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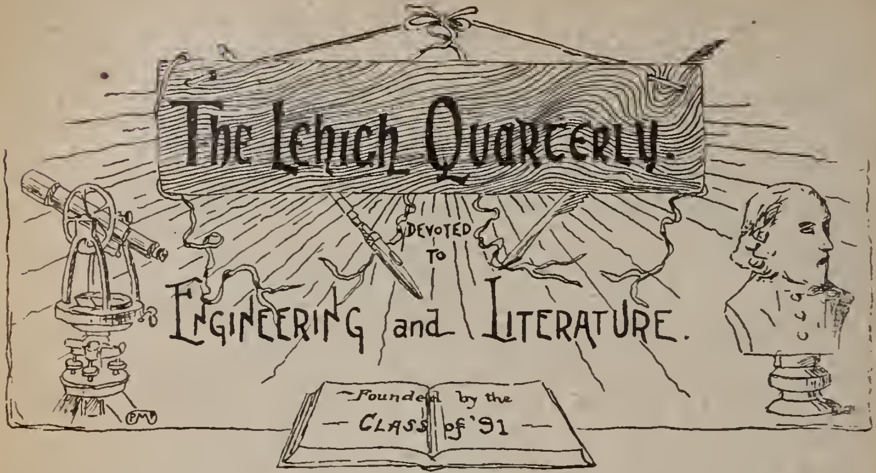

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Vol. II. OCTOBER, 1892. No. 4.

THE READING COMBINATION FROM THE STANDPOINT OF THE MINER.

The following article is an endeavor to examine the effect of a union of interests upon the mining industry, without regard to the personality of the parties who form the union, their motive for so doing, or the bearing of that union upon the body of consumers of the product mined. It will have no effect on the end reached that the product is anthracite coal, as it may be any other economic substance, though a point will be raised during the treatment of the topic that will be based on the fact that it is *anthracite* that is mined. In this discussion the writer endeavors to put out of sight the fact, that opposition to the combination has been made, and efforts to break it have been set in operation. The deductions, therefore, will be beyond the reach of criticism from the standpoints that have been excluded.

The facts of the case are that the Reading management has obtained control, directly or indirectly, of the greater part of the anthracite producing mines; it has raised wages and cost of product, and means to continue to hold the power now possessed. This article is written to show from the standpoint of the miner that such a combination is needed for anthracite coal in particular, and that it would be well if all mining interests were consolidated, preferably in the hands of the government, as present methods of mining are wasteful, lawless, and governed more by policy than by justice and common sense. Here and there are brilliant exceptions, but these only prove the rule to be as stated. In other words, here is another case where, in a free people, liberty has degenerated into license. It will be necessary to review the subject for many years past under the heads of mining, supplies, expenses and labor, and we may find that the alleged "Robber Barons" are subjects rather of commiseration than envy.

First, when the mines were opened, there was a great demand for coal, and the land owners worked their properties or leased them at high royalties to corporations or individuals. The State imposed no restrictions or burdens, and each one mined as he chose. The outcrops were intact, the body worked was near the surface, so that haulage was at a minimum, as were pumping, ventilation, and timbering. As the mines extended, the periphery of the workings became longer, and the area excavated larger. The exhaustion of upper beds required deeper shafts and slopes, tunnels through rock, and other classes of "dead," or unproductive work, as well as larger and more expensive plant for haulage and hoisting, while the extension of the workings in area and depth necessitated larger machines to meet the increasing water and foulness of air.

Second, the timber supplies were obtained with a minimum of cost, as the country was generally wooded when mining began. Little timber was required in comparison with what was afterwards necessary, as there was by no means so great a body of rock to support near the outcrop as when the mines were deeper. As the supply in the neighborhood became exhausted, the costs were raised, and the additional item of transportation tolls to bring the supply from a distance was added. In this item, there has been a gradual increase from the time of commencement to the present day, and this increase has been extended to other items. In another way, the amount of timber needed has been increased, as the increased depth from the surface required a greater proportion of timber per ton of mineral mined, as will be shown more fully under the head of expenses; the size and quality of the timber has become a matter of the first importance, so that the cost has been greatly increased, and in some cases has become almost prohibitory. Attempts have been made to substitute some other material, or change the method of mining.

Third, under expenses, will be grouped a number of subjects that bear upon the cost of the mineral at the surface, and ready for shipment. As the matter now stands, there has been nothing said about repairs or replacement of stock or plant. If a mine once opened would keep itself open after it has been once secured, the matter would be much simplified; but the fact is that there never comes a time, till the whole area has caved in, when anything like security can be felt. For a time after the opening of the gallery or working place, there is a season of quiet till the superincumbent masses settle upon the timber or pillars left for their support. If the supports are insufficient, they must be strengthened, or there will enter a new item into the account—that of loss from caving in of the excavation, and the attendant losses from inability to work that part of the mine, as well as the cost of replacing the necessary supports after reopening the working places. In case the first supports are sufficient, we must be on the watch for decay of timber, disintegration of roof or floor, or movement of either that will endanger the stability of what is already in place. If the rock is sandstone it will not be affected by the dampness in the air; but if it be of a clayey nature, we shall have swelling of the top or creeping of the bottom. If none of these occur, we shall have the timber rot with time, and more quickly in proportion to want of proper ventilation. It may be that the surface is worthless and need not be supported; but this will not be the case where surface rights are valuable, or where bodies of water will enter through the cracks made by settling. The timber must be replaced from time to time throughout its whole extent, and its cost increased as supplies become scarcer, or as labor is more valuable. In the same way the haulage account will be increased, in addition to the items already given, by the wear of track and wagons and their replacement. In case mechanical motors, or swift systems of haulage are employed, a heavier rail and a more strongly built track become obligatory, and all must be replaced and repaired from time to time. In some cases where the mine is an old one, and of great extent, there will be direct haulage of over a mile from working face to foot of shaft or slope. The same argument can be applied to repairs of shafts, motive power, and all things that combine to bring the mineral to daylight. By and by, the state made its appearance as an imposer of certain necessary, and some very unnecessary, conditions that added to the cost of working, such as twin openings: a minimum of air supply: a regular police of the mine, and an accurate survey for the inspector's map, as well as many minor thorns in the flesh—necessary; but unpleasant and expensive.

When we think of the cost of a substance, we too often stop with those operations that bear directly upon its creation. The cost of a ton of mineral includes a living and a dead load. The living load comprises all costs that bear directly upon the getting it to the dump, such as mining, haulage, hoisting, pumping, ventilation and stocking or loading on cars. The dead load is independent of the quantity mined, and exists as long as mining operations continue, or until the mine in abandoned. This includes interest on capital; all sinking funds, fixed salaries, office and clerical expenses and, in the case of an unworked mine that must be kept open, fuel sufficient to furnish steam for pumping and getting supplies into the mine, an extra force for police of mine and for repairing and keeping open working places. In the case of a mine worked on full time, the miners act as police, and each man keeps in repair his own place, and notes points of danger as he goes in and out, and gets his pay only for the amount mined. In other words, the mineral bears these expenses, and changes them from the dead to the living account. If the firm has a number of mines and one is idle, the working mines carry the idle one on their backs. If one ton of coal per day is taken out of one of five mines, it must bear the total of the loads. If 1500 tons are taken out of each of the five, the 7500 tons divide the living load only, as these is no dead one, and the chances of a profit is plainly seen. This subject is developed thus thoroughly, as the state of the Anthracite region will be discussed under this head, and the cause of loss in mining shown. There are other subordinate items that might be noted would the limits of this article permit.

Fourth, labor is the straw that has broken the back of the anthracite camel. Beginning with the opening of the mines, we find a demand for coal and labor. To discuss the labor question, we must know what is required of the miner. "Winning" coal may be divided into "dead" and "paying" work. The former comprises all drivages where the mineral obtained does not pay for the work; the latter where the opposite obtains. The former includes the reaching and developing the deposit by shafts, slopes, or levels; the latter consists in "breaking it down" so that it can be handled. Workmen in the former are paid by the "shift," or by the distance driven, and frequently such work is done by a firm who obtain a contract by a successful bid, so that, generally, "rock men" make good wages in any condition of the trade, as their own bids fix their income. Workmen in the latter are called "miners," and to one or two is given the care of a "room," "breast," etc., and they furnish all supplies for "breaking down" coal, lay all tracks, and set all timber from supplies hauled by the company to the mouth of their rooms. A certain number of empty cars (varying with the market) are hauled daily to the face of the room at stated times, and the men are paid a certain price for each car when filled to a given mark. Their income, therefore, depends on the number of cars, and that varies with the market. They can hire all the labor they require, they need do no more than superintend such labor. The time necessary to break down the coal to fill these cars depends on the dip and thickness of the bed, its nature, and the width of the room. In the best cases the work can be done in a few hours; in the worst, and where much timber must be set, the miner will be kept busy eight or ten hours. The writer has been told of cases, in the golden days of anthracite, where the miner went to California while his laborers filled the cars. He knows some who came with pick and shovel, and who are now wealthy. They have been mayors of cities, sheriffs and treasurers of counties, presidents of banks, of colliery companies, and of iron works. Their children are college-bred and "in society." It was so easy for a good miner to make money by a short spell of hard work; so much easier than in other occupations that a man who has once been tarred with a mining brush can never rub it off. They may undertake other tasks, but the work will be more confining, and wages smaller in proportion to the time spent, and back they go to swell an already overcharged labor market.

To resume, the multiplication of collieries produced an overcrowded market for both coal and labor, and the prices of both fell. The operators, during the latter part of the '60's, among other retrenchments, cut wages to meet their diminished receipts and the increase in costs mentioned before. Then came the great organization that struck successfully for the "sliding scale" of wages. That success encouraged succeeding strikes, and was the cause of the present condition of mining labor in the coal regions. In 1869 the country was shocked by the terrible disaster at Avondale, and during the following year the Pennsylvania Legislature enacted the "Ventilation Law," which increased the burden of the operators by compelling them to have two distinct openings to every bed worked; to pass a minimum supply of air through the workings per capita; to maintain a police system for the detection of fire damp, and to make considerable expenditures for surveys and maps. Some operators were earning so little that it was cheaper to allow their mines to fill with water than to make the second opening; others were compelled to make it or lose their capital. The expenses were thus greatly increased and the profits diminished. Then came the depression of 1872–3. Many mines were closed. Others were opened under leases that called for greatly diminished royalties. These latter, with small expenses for haulage, pumping, and ventilation, were alone able to make profits. During the times of prosperity the great companies were formed. They had bought extensively and leased at high royalties. Their time for moderate expenses passed long ago, and over some of them the cloud that settled in 1872 has never lifted, as the depression affected the iron manufacturers of the country, forcing some to shut up, and compelling the survivors to change their methods. When prosperity came, coke had taken the place of anthracite, and it has steadily been forcing it from its former position.

The miners met the cut in prices by strikes that generally failed, and worse than failed, as their end did not place their authors in their old working places. Those places were filled by outsiders who did not take to heart the lesson of which they were the exponents, but struck to give places to others. When the neighborhood had been exhausted, the country at large was drawn upon, and finally the Old World sent its dregs to enlarge the already swollen labor body. Not long ago a report of one of the great companies showed three times the number of miners in its district than were necessary to run all the mines on full time. It also showed that the company lost, during the year, a few cents on each of the millions of tons it had mined. We have partially studied the subject of "dead loads" in the expense column. There is a demand for a certain amount of coal per annum, and there are three times as many men as can work. If we could take the cheapest third and set all the mines going on full time, the output would double the demand. We must take, therefore, but one-sixth of the men, and either place them in one-half the mines, which we will run on full time, or we must distribute them through all the mines and work them at such a proportion of full time that the output will equal the demand. The former method would be best for operators and miners, if the abandoned mines would take care of themselves. But, as we have seen, this is impossible. The only way out of the trouble is the one taken by the Reading management in uniting all anthracite interests. Let us investigate the subject under the head of saving in cost of mining when the mines are contiguous.

It is a matter of indifference whether we are working beds or veins, as long as we have a number of mines in the same district, with a general relative location to the drainage level of the country. If these mines are worked by individuals, they must be separated by boundary pillars, and as completely isolated as the circumstances will allow. Each mine must have its separate plant for hoisting, ventilating and pumping, its side tracks for loading, its lands for dumping refuse, and the thousand and one minutiæ that obtain in a mine of the first class. Some may have less water to pump than others, or the location of the ground allows an adit for drainage or haulage. The advantages of one do not affect the others in the least, while the accidents of one may be communicated to those adjacent. By the separate system, there are evils that are unbalanced by benefits of any kind. If we can combine these mines under one management, by purchase or confederation we can make use of the advantages of each to benefit the whole, and can make the advantages conduce to the general profit, if the mines are owned by one company, or can tax the mines for the advantages they obtain from the favorable conditions of others in the combination, and let this sum offset the dues exacted from such favored mines. In case an extended work will afford ventilation or drainage, or haulage, or methods of mining of a more efficient nature, we can tax each mine for its quota of capital to do the work, and let each have the advantage of the new system. We can cut off numbers of names from the pay rolls, dispense with certain openings, and concentrate our work of hoisting to those places where it can be performed most cheaply; clear the refuse from certain lands and use for dumping only lands that are worthless, and in many other ways concentrate our work and cut down expenses. Our supplies will cost us less, because we buy in very much larger quantities, and the concentration of plant will diminish their amount and the cost of production. In the case of the anthracite mines in a given basin, we can, perhaps, put through an extended drainage adit that will do away with pumping above a given level, and allow us to accumulate water for motive power to pump all water that forms below the level of the adit. If the water supply is sufficient, we can utilize it to hoist ore from the mine below the adit-level. The waste water, in both cases, will run out of the adit. The number of upper mine superintendents will be cut down, and each one retained will have a number of mines that will be worked in common, and the work will be laid out so as to cover the whole area mined, and will not stop at the boundaries of each small property. This will cut down mining expenses. In case there are chances to strip land and work open-cut, such work can be done in connection with underground mining in the neighborhood, so as to dispose of the overburden, and diminish haulage and dumping expenses for its removal. The curtailment of expenses and concentration of work will result in a saving of money and greater profit for the company, as well as better wages for the miners. It may be possible for a large company to devise new methods for saving waste in mining, as a large company can afford to spend money in experimenting, while a small operator would be obliged to attend strictly to business in order to make both ends meet under competition. Lastly, and by no means the least of the savings, there would be no competition to unsettle trade. If all the mines that produced a certain product of an acquired value were controlled by one management, the market would be kept supplied and never glutted, the miners would be in clover and have as good wages as the company could afford to pay. As the value of the product is *acquired*, it could never go above the price created by the demand, and the company could make great profits by cutting down expenses. The Standard Oil Company is an example of such a combination. Although there has been a series of fortunes made by the members of the company, and though the workmen have had all the work they wanted and have also made money, the public has also benefited by the reduction in the price of the commodity, by the curtailment of expenses along the lines noted above, and by devising new and cheaper methods for doing the work. In this way we can see that a combination by the Reading Company, or any other company that could control the whole of the anthracite mines, would not be an unmixed evil. It might raise the cost of coal at first till it paid to mine, and then it would exhaust the mines now in operation, and not open new ones till there was a demand for them. In this way there would be no dead expenses to be carried by working mines, as all the mines would be at work, and all the men in them would have full time. In time there would be no idle mines and no dead load in the expense column, so that the cost of the product could be reduced and a profit still made. At present the only way out of the tangle is for the companies to restrict product and raise the price of coal. With a rigid combination that controls the whole anthracite region, we shall have no opening of new collieries; but, as some of those now working become exhausted, we shall find better times coming for the operatives in the remainder, until the output of all the collieries, when on full time, equals the demand, and then we shall have prosperity for Capital and Labor. Labor, however, must have learned its lesson, and must show that it has been learned, by restricting the number of operatives and by stopping the senseless practice of killing the goose that lays the golden eggs — striking.

The last point is that the price of anthracite can never be unduly raised, as our vast fields of bituminous coal stand ready to flood the market when hard coal reaches a certain figure. It costs less to mine and ship soft than hard coal and, beyond this, the control of the soft coal and coke trade lies in the hands of an enemy of the combination—the Pennsylvania Railroad. Even with a low price for anthracite, it has been driven out of many industries by coke, and an increased price means extended victories for the latter, if not a flooding of the market by bituminous coal.

EDWARD H. WILLIAMS, JR.

A DETERMINATION OF THE ECCENTRICITY OF A SEXTANT.

There is a very large class of observations, wherein an extremely light and portable instrument is desired, but one which must give reliable results within the limit of accuracy of such work. At the same time it must be easily handled, and not so constructed as to complicate the reductions with instrumental errors difficult to investigate.

The Sextant fills this place so well that it has become almost indispensable to the explorer and navigator. The former finds that with it he can easily and rapidly determine the approximate latitude and time, and the latter finds it indispensable for determining, not only these, but the longitude of his ship also when it becomes necessary.

Although not usually relied on for very exact work, it has been shown* that a surprising degree of accuracy can be obtained with this instrument, when the errors have been properly investigated. Most of them have so small an effect that with a good sextant their investigation is unnecessary for the kind of work which will be ordinarily undertaken, but with the error known as eccentricity it is quite otherwise.

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* "The correction of Sextants for eccentricity and graduation," page 33, (Published by the Smithsonian Institution, 1890). See also "The Sextant," by W. H. Simms, (Published by Troughton & Simms, 158 Fleet Street, London, 1858.) for a thorough discussion of the subject.

This is an error due to the centre about which the alidade revolves not being in the exact centre of the graduated arc. Its effect is very noticeable, even in rough observations. In a special instrument, "upon which extraordinary pains were bestowed,"* it produced an error of twenty seconds of arc, while in ordinary instruments it varies from this up to five minutes. The latter value would give rise to an error of ten minutes of time in observing, say a lunar distance for longitude, which might make the final result wrong by nearly twelve miles, even were the measurements made with perfect accuracy.

These errors are not surprising when we consider that a misplacement of but one one-thousandth of an inch in the position of the centre might produce, in a sextant of seven inch radius, an error of more than fifty seconds of arc.

There has been an instrument invented for determining these effects of eccentricity,* but it is usually done by measuring the altitudes of stars or the distances between them. The angles thus obtained with the sextant are compared with their true values, and the eccentricity computed from the errors thus found.

Suppose a straight line drawn between the two centers and prolonged until it meets the graduated arc.

Let a be the number of degrees between the zero point of the limb and the point of intersection.

Let e'' be the distance between the two centers, measured in seconds of arc on the limb.

Let u be the true value of an angle, and u^1 its value as obtained by measurement: we will have the formula:

$$u - u^1 = 4e'' \sin \tfrac{1}{4} u \cos \left(\tfrac{1}{4} u - a\right) \qquad (1)$$

which becomes by expanding $\cos\left(\tfrac{1}{4} u - a\right)$

$$u - u^1 = (4\,e'' \cos a) \sin \tfrac{1}{4} u \cos \tfrac{1}{4} u + (4\,e'' \sin a) \sin^2 \left(\tfrac{1}{4} u\right) \qquad (2)$$

---

* See "The Correction of Sextants," before referred to.

In this equation e'' and α are the unknown quantities. Two observations would be sufficient for their determination, though of course many more are taken, and the results combined by the methods of least squares. It is also best to introduce a new unknown quantity z, to represent all constant errors not due to eccentricity. This will usually be largely made up of the constant error the observer makes in determining the Index correction.

We will write $4\, e'' \cos \alpha = x$; $4\, e'' \sin \alpha = y$; $u - u^1 = N$. (3)
Then (2) becomes $(\sin \tfrac{1}{4} u \cos \tfrac{1}{4} u)\, x + (\sin^2 \tfrac{1}{4} u)\, y + z = N$. (4)
where the quantities in parenthesis and the absolute term may be computed for each star.

1. TO DETERMINE THE VALUE OF u.—If we are measuring the altitude of a star, u will evidently be it's true double altitude + twice the displacement due to refraction ± the index correction, since u represents the reading we should obtain with our sextant.

Considering the spherical triangle formed by the zenith, the pole, and the star, we may write at once

$$\begin{aligned} \cos h \cos a &= \cos \delta \cos t \sin \phi - \sin \delta \cos \phi \\ \cos h \sin a &= \cos \delta \sin t \\ \sin h &= \cos \delta \cos t \cos \phi + \sin \delta \sin \phi \end{aligned}$$

which equations, adopted to logarithmic computation in the usual way*, become

$$\begin{aligned} \tan M &= \tan \delta \sec t \\ \tan a &= \cos M \tan t \operatorname{cosec} (\phi - M) \\ \tan h &= \cos a \cot (\phi - M) \\ \cos M \operatorname{cosec} (\phi - M) &= \cos \delta \cos t \sec h \sec a \end{aligned} \qquad (5)$$

where δ and α are the declination and right ascension respectively, as found from the ephemeris; a and M may be regarded as auxilliary quantities; ϕ is the latitude, which may, if necessary, be deduced from the observations themselves; h is the true altitude, and t is the hour angle, from the equation

$$t = \theta - \alpha \qquad (6)$$

where θ, the sidereal time, must be known.

---

* Chauvenet's "Spherical Trigonometry," Art. 70, *et seq.*

The effect of refraction is to increase the altitude. Its value is found by the equation

$$r = k \tan z \; b.s.t. \tag{7}$$

Where z is the zenith distance; k is a factor varying with z; b, s and t are also varying factors, which depend upon the readings of the barometer, the thermometer attached to it, and the detached thermometer respectively. The values of these factors are given in tables, where the argument is usually h, as found by (5).

Lastly, the index correction is found by taking several readings on a star in the usual way.

We will then have

$$2\,(h + r) \pm I = u. \tag{8}$$

The problem is not quite so simple a one when we are measuring the distances between two stars. This is because we must determine the effect of refraction upon their right ascensions and declinations before applying the formula for distance; otherwise we would obtain the true, and not the apparent, distance between them.

From the spherical triangle we have just been considering we may deduce the following formulæ, wherein q is the angle at the star:

$$\left.\begin{aligned}
\tan N_1 &= \cot \phi \cos t,\\
\tan q &= \sin N_1 \tan t \sec(\delta + N_1),\\
\tan z &= \cot(\delta + N_1) \sec q,\\
\sin N_1 \sec(\delta + N_1) &= \cos \phi \cos z \sec q.
\end{aligned}\right\} \quad (9)$$

We thus obtain z and q, when, by (7), r may be found. The effect of r in α and δ is then found from the differential formulæ.*

$$\left.\begin{aligned}
d\delta &= -\, r \cos q,\\
d\alpha &= -\, r \sin q \sec \delta.
\end{aligned}\right\} \quad (10)$$

These corrections must be applied to the values of α and δ as found from the Nautical Almanac. They must of course be separately computed for each star: the new values thus obtained are the ones to be used in computing the distance. The formulæ is merely the solution of a spherical triangle, formed by the two stars and the pole.

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* Doolittle's Practical Astronomy, Art. 87.

Letting α and δ be the corrected right ascension and declination of one star, and α^{I}, δ^{I} those of the other we will have

$$\left.\begin{aligned} \tan N_2 &= \cot\delta\cos(\alpha^{\mathrm{I}} - \alpha) \\ \tan B &= \sin N_2 \tan(\alpha^{\mathrm{I}} - \alpha)\sec(N_2 + \delta^{\mathrm{I}}) \\ \tan d &= \cot(N_2 + \delta^{\mathrm{I}})\sec B \\ \sin N_2 \sec(N_2 + \delta^{\mathrm{I}}) &= \cos\delta\cos(\alpha^{\mathrm{I}} - \alpha)\operatorname{cosec} d \sec B \end{aligned}\right\} \quad (11)$$

The last equation here, as well as in (5) and (9) enables us to prove our work.

We thus obtain d which is the apparent distance. Then

$$u = d \pm I \quad (12)$$

2. TO DETERMINE THE CO-EFFICIENTS OF x AND y.—The value of u, as determined from equations (12) or (8), is the true value of the measured angle. The error due to eccentricity, however, must not be applied as a correction at this point of the arc, but at the point where the coincidence of the vernier and limb takes place. We might set off on the graduated arc the angle u, and observe where this fell. It is the best way, however, to observe at what point there is coincidence for each reading taken. The mean of these gives the value of u to be used in computing our coefficients.

3. TO DETERMINE THE ABSOLUTE TERM.—In the measurement of angles for the determination of u^{I}, the observer should unhesitatingly reject all which do not come up to what he considers as the best work of which he is capable under the given conditions. For it is evident that if the corrections are carelessly determined, it is useless to attempt accurate work with the instrument afterward.

However carefully subsequent observations may be made, the result will be subject to the errors to be found in the table of corrections.

These remarks apply to the determination of all instrumental errors.

The index correction should be carefully determined several times, and if it is found to have varied considerably at any one time, the observations made then should be rejected also. All such rejection should be made however, before the reduction of the observations has been begun, and it should not be done merely to make the final results harmonize among themselves.

Having u^1, N follows from (3)

Having then from several stars determined x, y and z by (4), we apply (3) and thus obtain $4e''$ and α. By substituting values for u in (1) for every five or ten degrees of the arc we may obtain a series of corresponding corrections $(u - u^1)$ at those points, due to eccentricity.

OBSERVATIONS.—The instrument of which the eccentricity was to be determined is a Pistor & Martin's, eight inch, prismatic sextant.

There were originally eighteen angles measured; fourteen of these were double altitudes of stars upon the meridian, the remaining four being distances.

It was found however that the results from the second method were far more reliable than from the first. This was evidently due to the rapid motion of the meridian stars, which sometimes rendered it necessary to lay the instrument down and move the mercury in the middle of a set of observations. The errors in recording time also, which would have no appreciable effect in measuring distances, here would lessen the accuracy considerably. As the apparent distance between two stars remains nearly constant for several seconds or longer, the images can be brought into coincidence with more care and deliberation, which also increases the advantage of this method.

Each set consisted of ten readings.* The time was taken by a mean time chronometer, each reading being reduced to sidereal time afterward.

As an illustration, an outline of the work of reducing the observations of one altitude and one distance will now be given.

On the second night, August 16th, 1892, the barometer read 29.786 in., the attached thermometer +74.1° F., and the detached thermometer +66.8° F. The index correction was then determined from ten readings, and found to be On Arc 16′ 40″. Five comparisons of the watch and sidereal clock were made; the mean error thus found was —12 hrs. 44 min. 18.6 sec.

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*It has been shown that with the sextant nothing is gained by extending the number beyond ten.

The distance between α *Aquilæ* and η *Ursæ Majoris* was next measured carefully ten times, the time of each observation being recorded. Each record was reduced to the corresponding clock time, by the usual formulæ, after which the clock correction, as determined by transits of stars was applied, and the mean of the final results taken to obtain θ.

The mean of the reduced times, or θ, was 19 hr. 51 min 01.9 sec.

The mean of the ten readings, or u^1, was 84° 04′ 20.″0.

From the ephemeris we find α and δ for α *Aquilæ* at this time to be

$$\alpha = 19 \text{ hr. } 45 \text{ min. } 33.2 \text{ sec.}$$
$$\delta = +8^\circ\ 34'\ 05''$$

Therefore by (6), $t = 1^\circ\ 22'\ 10''$. Also $\varphi = 40^\circ\ 36'\ 24''$

By substituting these quantities in (9) we find q and z to have the values 1° 57′ 32″ and 32° 03′ 40″, respectively.

Applying then equation (7), we find the *log* of r to be 1.54419. After which the computation proceeds by (10) as follows:

$$\log\cos q = 9.99975 \qquad \log\sin q = 8.53380$$
$$\log r = 1.54419\,n \qquad \log r\sin q = 0.07790\,n$$
$$\underline{d\delta = +34''.99} \qquad 15\cos\delta = 1.17121 \qquad \underline{d\alpha = +0.08\,s}$$

r is here made negative as its effect is to decrease the zenith distance.

We now interpolate in the ephemeris for the exact values of α and δ, and apply the above corrections to them. We find, finally,

$$\alpha^1 = 19 \text{ hrs. } 45 \text{ min. } 33.31 \text{ sec.}$$
$$\delta^1 = 49^\circ \quad 35' \quad 39''.99$$

Correcting in a similar manner the co-ordinates of η *Ursæ Majoris*, there was found

$$\alpha = 13 \text{ hrs. } 43 \text{ min. } 26.26 \text{ sec.}$$
$$\delta = 49^\circ \quad 51' \quad 38''.30$$

These values are the ones to be substituted in (11) for determining δ, which, in this case, will be found to have the value 83° 46′ 41″.5. Hence by formula (12), since the reading is on arc,

$$u = 83^\circ\ 46'\ 41''.5 + 16'\ 40'' = 84^\circ\ 03'\ 21''.5.$$

And $(u - u^{\text{I}})$, which is the absolute term of our equation,

$$= 84^\circ\ 03'\ 21''.5 - 84^\circ\ 04'\ 20''.0 = \underline{-5.8''.5}.$$

The mean of the ten points of coincidence was found to be $87^\circ\ 44'$. Therefore $\frac{1}{4}\,u = 21^\circ\ 58'$, and our equation for these stars becomes

$$0.3465\,x + 0.1395\,y + z = -58''.5.$$

As an example of altitude reduction, we will take α *Aquarii*, the next meridian star observed.

The index correction was found to have the value $16'\ 35''$ on arc.

The mean of the observed double altitudes $= u^{\text{I}}$, was $97^\circ\ 24'\ 18''.3$; of the points of coincidence, $= 4\,(\frac{1}{4}\,u)$, it was $101^\circ\ 48'$, and the mean of the reduced times was 22 hrs. 06 min. 27.03 sec.

δ and α from the ephemeris have the values $-0^\circ\ 50'\ 29''.3$ and 22 hrs. 00 min. 16.80 sec. respectively. Therefore $t = 1^\circ\ 32'\ 33''.4$, and by applying (5), we find h to have the value $48^\circ\ 32'\ 30''.7$.

The refraction is found by (7), where $z = 90^\circ - h$; its value is $+ 49''.8$.

Then u follows directly from (8);

$$u = 2\,(48^\circ\ 32'\ 30''.7 + 49''.8) + 16'\ 35'' = 97^\circ\ 23'\ 16''.0$$
$$\text{and } (u - u^{\text{I}}) = -62''3.$$

So with this star our equation becomes

$$0.3880\,x + 0.1847\,y + z = -62''.3.$$

In this way the equations of condition were formed. They were rendered homogeneous, and then solved for x, y, and z, with the following result:

$$x = -58''.77 \pm 56''.21,$$
$$y = -151''.64 \pm 84''.75,$$
$$z = -8''.20 \pm 7''.75.$$

By (3) we now find

$$4e'' = -162''.41.$$
$$\alpha = +68^\circ\ 47'\ 14''$$

We lastly substitute different values for u in equation (1), and thus obtain $(u - u^1)$. For example, we have with 10°,

$$(u - u^1) = -162''.42 \, sin(2\tfrac{1}{2}^\circ) \, cos(2\tfrac{1}{2}^\circ - 68^\circ \, 47' \, 14'') = -2''.8.$$

It is a question whether the constant z should or should not be added to this quantity.

If z is due to some permanent displacement of any part of the instrument, it should be added. If, however, it arises from the personal error in determining the index correction, it should not.

It was found, in investigating this instrument several years ago, that the addition of z seemed to over-correct the eccentricity. We however add it now, that the results may be compared more readily. Hence the corrections $= (u - u^1) + z$.

In this manner the following table was computed. It will be found to agree reasonably well with the first one, although eccentricity is somewhat liable to change.

Corrections June 22, 1889.		Corrections Aug. 17, 1892.	
ANGLE.	CORRECTION.	ANGLE.	CORRECTION.
0°	—11″.9	0°	— 8″.2
10°	—14″.5	10°	—11″.0
20°	—17″.3	20°	—14″.4
30°	—20″.2	30°	—18″.4
40°	—23″.4	40°	—22″.8
50°	—26″.7	50°	—27″.6
60°	—30″.1	60°	—33″.0
70°	—33″.6	70°	—38″.7
80°	—37″.2	80°	—44″.8
90°	—40″.8	90°	—51″.1
100°	—44″.4	100°	—57″.6
110°	—48″.0	110°	—64″.5
120°	—51″.6	120°	—71″.5
130°	—55″.1	130°	—78″.5
140°	———	140°	—85″.6

August 30th, 1892.

ERIC DOOLITTLE, '91

CRYSTAL DRAWING.

The object of this article is to deal with that feature of the subject least fully dwelt upon in Dana's mineralogy and the lectures of Prof. Frazier, the drawing of the simple crystalline forms.

In beginning the study of crystallography as an introduction to determinative mineralogy, one of the chief failings is apt to be an inability to readily recognize the figure from the symbol and *vice versa*. Another is in a failure to perceive the relations existing between different forms.

One should be careful, however, not to fall into the error of supposing that determinative crystallography is the only field of the science. On the contrary, it has intimate relationship with molecular structure and the laws of crystallization are just as fixed as the laws of chemistry. One peculiar illustration of this is in the polarization of light by tartaric acid. A salt of this acid can be obtained in hemihedrons, a part of the crystals having hemihedral faces similar to those on the other crystals when held before a mirror. On separating and dissolving them, and freeing the acid, one solution is found to turn the plane of polarization to the right, the other turning it to the left.

When these solutions are united they form racemic acid, an acid of just twice the molecular weight, but inactive in polarizing light.

The relation between the composition and method of crystallization is also very well shown by the similarity existing among the sulphates of barium, strontium, calcium, and lead; the angle $I \wedge I$ varying between 100° 30′ and 104° 02′. The carbonates exhibit a similar relation.

Many of the prettiest theories of stereo-chemistry are based on such suppositions as that an atom of carbon acts like a tetrahedron with unsatisfied chemical affinity existing at the four vertices.

The importance of crystallography as bearing upon mineralogy is probably often underestimated. The majority of tests, as lustre, color, and hardness are purely relative. Where a crystalline form occurs, however, it can be identified with mathematical certainty.

There are a few fundamental laws which, well understood and applied, will go far towards a good comprehension of the subject. Such are the laws of simple mathematical ratio, of symmetry, and of zones and their correllaries, as the constancy of angle in the same species. But these are fully explained elsewhere, and space will not permit their repetition.

Drawing a crystal is a valuable exercise, thoroughly instilling a knowledge and observance of the laws just mentioned, and giving an ability to recognize in practice, at least the figure which has been drawn. There is one difference, however, which should be borne in mind. The figure drawn is a perfect crystal, one in which all the faces possible to that form occur, and one in which the linear distance cut off by one face on any axis is the same as the linear distance cut by another face on its corresponding axis. In nature these model crystals are not apt to occur, but are distorted in process of formation by adjacent material. In cleavage pieces especially, a plane may be at any distance from the center, and has no regard whatever for the distances observed by other planes.

The six crystallographic systems are arranged according to the amount of symmetry they possess. The isometric system, containing the most symmetrical of all geometrical solids, is placed at the head, and its forms are the most difficult to construct. As drawings of the isometric and hexagonal system only are required, no attention will be paid to the other four, but by an application of the same principles any form of any system may be drawn.

A crystal could be drawn as it would appear to an observer near to it, or as it would appear to him if situated at an infinite distance, supposing that it still preserved finite proportions to the eye. The latter method is the one employed. The lines of sight to all parts are parallel, and parallel edges appear as such, bringing the zones into prominence. The labor of drawing is likewise simplified, as the figure is orthographically projected upon the plane of the paper.

THE AXES.—The three main axes of the isometric system are identical with the three axes of solid analytical geometry, and the first step being to represent them upon the paper, the question arises as to what will be the most favorable direction in which to view them and to draw them in that position. As a unit distance is the same linear distance on each axis, a sphere of unit radius, with its centre at the origin, would contain the ends of the unit axes in its surface. To render the following discussion more clear, suppose such a sphere to exist as in Fig. 1. But an observer whose eye is placed in the line *OY*, extended, of Fig. 1, would see axis *OY* projected as a point at *O*, while *OX* and *OZ* would appear at their real value. This would not be so advantageous a position in which to view the crystal as one in which the three axes would be seen as lines inclined to each other and of unequal length. To effect this, rotate the sphere through an angle *YZA*, about the vertical axis, then revolve it on *O* as a center, tipping the vertical axis toward the observer through an angle of 90° — *ZOA*, but keeping it in the same vertical plane. As these revolutions are purely relative we may suppose the observer to have moved in the contrary directions, and in his final position the line of sight will be along some line as *OAN*. The vertical axis will then appear as *C*, and the horizontal axes as *a* and *b*, being projections on a plane perpendicular to *ON*.

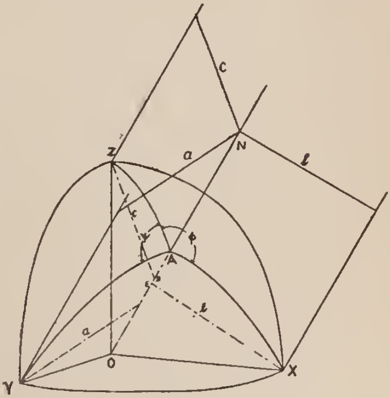

FIG. 1.

b will be inclined to C at an angle φ.
a will be inclined to C at an angle ψ.

We then have six variable quantities, R, a, b, c, ϕ and ψ, any three of which being fixed, the rest are determinable, and the direction of sight OA is found.

Dana's method, page 463, Dana's Mineralogy, gives R, ϕ, ψ, to determine a, b, c.

Prof. Frazier's method is to give a, b, c, and determine ϕ, ψ, it being unnecessary to find R.

The detailed proof of this method is reserved for another page that the reader may skip it if so inclined.

Assuming any ratio for a, b, c so that

$$a^2 < b^2 + c^2$$
$$b^2 < a^2 + c^2$$
$$c^2 < a^2 + b^2$$

We have: $$\cos\phi = -\frac{\sqrt{(a^2 - b^2 + c^2)(a^2 + b^2 - c^2)}}{2bc}$$

$$\cos\psi = -\frac{\sqrt{(a^2 + b^2 - c^2)(b^2 + c^2 - a^2)}}{2ac}$$

If $a : b : c = 5 : 9 : 10$

$$\phi = 95^\circ\ 11',\ \psi = 107^\circ\ 49'$$
$$\tan 5^\circ\ 11' = \tfrac{1}{11};\ \tan 17^\circ\ 49' = \tfrac{9}{28}.$$

Therefore, to construct these axes lay off a horizontal and a vertical line as XX' and YY' Fig. 2.

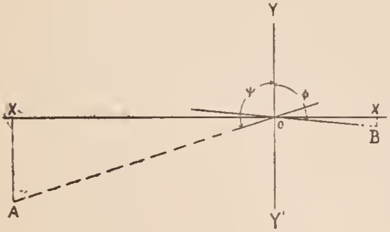

FIG. 2.

Measure 28 on OX' to X' and down 9 to A. Then $\tan X'OA = \frac{9}{28}$, and $YOA = 117^\circ\ 49'$. Measure 11 OX to X and down 1 to B. Then $\tan XOB = \frac{1}{11}$, and $YOB = 95^\circ\ 11'$. Lay off on OA a distance of 5 in each direction from O and on OB distances of 9. On YY' lay off 10 each way. We now have what represents a unit length on each axis, though none of them appear at their real value on account of fore-shortening.

The proof of the work is as follows: $a^2 < b^2 + c^2$, for a^2 will be a maximum and $b^2 + c^2$ a minimum when A lies in the plane ZOX (Fig. 1). But when such is the case triangle $ZOD = XOE$ and $b^2 + c^2 = R^2$. But $a = YO = R$ and therefore $a^2 = b^2 + c^2$ is the limiting value, or in general, $a^2 < b^2 + c^2$.

To find the value of $\cos\phi$ in terms of $a\,b\,c$ let $XOA = X$, $YOA = Y$, $ZOA = Z$. Then

$$\sin X = \frac{b}{R}; \qquad \cos X = \frac{R^2 - b^2}{R^2};$$

$$\sin Y = \frac{a}{R}; \qquad \cos Y = \frac{R^2 - a^2}{R^2};$$

$$\sin Z = \frac{c}{R}; \qquad \cos Z = \frac{R^2 - c^2}{R^2};$$

But $\cos^2 X + \cos^2 Y + \cos^2 Z = I$,

(Davies Bk. VIII, Prop. I., Sch. IV.)

and substituting:

$$\frac{R^2 - a^2}{R^2} + \frac{R^2 - b^2}{R^2} + \frac{R^2 - c^2}{R^2} = 1\,; \quad R^2 = \frac{a^2 + b^2 + c^2}{2}$$

In spherical triangle ZAX

$$\cos \phi = \frac{\cos zx - \cos Z \cos X}{\sin Z \sin X} \quad \text{(Olney Trig. p. 97)}$$

But $zx = 90°$ and $\cos zx = 0$

$$\cos \phi = -\frac{\cos Z \cos X}{\sin Z \sin X} = -\frac{\sqrt{(R^2 - c^2)\,(R^2 - b^2)}}{bc}$$

Substituting the value of R;

$$\cos \phi = -\frac{\sqrt{(a^2 + b^2 - c^2)\,(a^2 - b^2 + c^2)}}{2bc}$$

In the same way

$$\cos \psi = -\frac{\sqrt{(a^2 + b^2 - c^2)\,(b^2 + c^2 - a^2)}}{2ac}$$

FORMS POSSIBLE TO THE ISOMETRIC SYSTEM.—In the isometric system only seven holohedral solids exist, but the total number of forms is increased by the two kinds of hemihedrism possible.

Hemiholohedral forms, those in which alternate octants are suppressed, can not exist in those solids which have the planes of one octant common to other octants; as the cube, rhombic dodecahedron and tetrahexahedron. For if one octant is suppressed and the adjacent ones continue to exist, their planes will be extended over the former position and the solid will repeat itself.

It will be noticed that these three figures are the limiting forms of the trapezohedron, trigonal trisoctahedron and hexoctahedron.

On the other hand holohemihedral forms can exist only when the holohedral solid has an even number of planes in each octant as otherwise alternate planes can not be chosen. This limits their occurrence to the tetrahexahedron and hexoctahedron. It is immaterial whether each face exists in one or two octants. There are, consequently, thirteen forms possible in the isometric system.

Before giving the method of drawing each form it will be well to set down rules applicable to all and in that way abridge the description of each.

1. Find the traces of the plane of each face on the coōrdinate planes as in Figs. 3 and 6.

2. Find the line of intersection of any two faces by finding two common points and joining them. As shown in Fig. 3 one of these points will usually lie on one of the axes and the other at the intersection of two traces on the coōrdinate plane perpendicular to that axis.

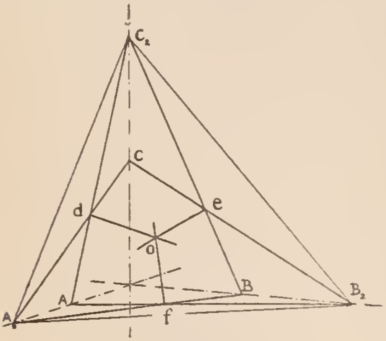

FIG. 3.

In Fig. 3 the intercepts on the axes cut by any plane are in the ratio of 2 : 2 : 1. All possible combinations occur in each octant, since in the isometric system all the axes are interchangeable. One plane will cut the axes at A, B_2, C_2, and its traces on the coōrdinate planes, found by joining these points, will be $A B_2$, $A C_2$, $B_2 C_2$. In like manner $B A_2 C_2$ and $C A_2 B_2$ determine the position of the other planes possible in this octant.

But $A_2 B_2 C$ and $B_2 C_2 A$ have a common point at B_2 and their traces intersect at d. Therefore, d being another common point, $B_2 d_1$ indefinitely extended, will be their line of intersection. In a similar manner $f o C_2$ and $e o A_2$ are the intersections of the two other pairs of planes.

3. Only that portion of each plane exists in the crystal which is nearer to the center than any other plane. Except in twin crystals no reëntering angles ever exist. In Fig. 3, therefore, the only portion of A_2B_2C existing in the figure is *c d o e* and of the other two planes only *B f o e* and *A f o d* remain. These quadrilaterals enclose the octant and complete that portion of the figure.

4. Repeat these operations for each octant, inking in some of the permanent lines if difficulty is found in distinguishing them from construction lines.

5. It will usually be found that one or more of the planes of the four front octants are invisible as in Figs. 4, 5, 7, 8. In that case an equal number of planes on the rear octants will come into view.

This is because in every holohedral crystal each face is parallel to one on the opposite side, and half the planes are always visible.

6. Be accurate in drawing, and place more reliance upon the intersection of two lines at a large angle than upon two nearly parallel.

In Fig. 3, *do* and *eo* should be drawn first to determine *o* as *f*, the intersection of AB_2 and A_2B is more liable to error. Accuracy of construction will be found of no small importance when developing the hemihedral form.

7. Checks on the accuracy of construction may be obtained by noting if all the lines drawn to a trigonal apex, such as the point *O*, Fig. 3, meet in a point, or if they include a small triangle. Also if the line joining any two trigonal apices, as a line *OQ* in Figs. 4 and 5 is parallel to a main axis.

METHOD OF DEVELOPING A HEMIHEDRON.—8. *a*. For illustration take Fig. 4 showing a cuproid (— 2.2) developed from a trapezohedron. All the faces in octants *P* and *O* cease to exist, and the faces in octants *N* and *Q* are extended until they meet each other. We can easily see that in any figure the intersection of faces continuing to exit will exist also and be extended till in contact with some other plane. Such lines are *NK*, *NG*, and *NH*.

b. All intersection between planes continuing to exist and those becoming imaginary will disappear. *af*, *ad*, *fb* are such lines.

c. Faces formerly separated by a plane no longer existing will be extended till they meet each other in new lines of intersection. *Na* and *Qa* are two such planes and they will meet in a new line of intersection *GK*.

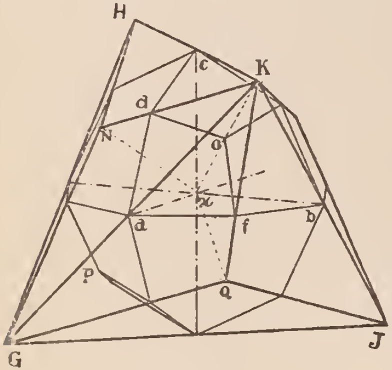

FIG. 4.

d. To determine these lines and also the new apices *G*, *H*, *J*, *K*, in which the extended planes meet, it is necessary to obtain two common points. One of these is obtained at the end of a main axis and the other by extending a line in each face similarly situated in respect to the center in order that they will intersect in space and not pass over or under each other.

In Fig. 4, *NK* and *QK* are two such lines. *NK* lies in the plane *NDOX* containing the trigonal interaxes *xN* and *xO* and therefore it cuts *xo* in some point *K*. *QK* lies in plane *XQfo* containing trigonal interaxes *xQ* and *xo* and therefore it cuts *xo* in some point *K*. It next remains to prove that *xK* is the same distance in each case. This can easily be done by constructing triangles and proving them equal. In Fig. 4 these construction lines *NK* and *QK* are also permanent lines, but in Fig. 5 such is not the case and their position is only indicated.

e. Another method of finding *G*, *H*, *J*, *K*, which often saves considerable labor is shown in Fig. 5. Having found *H* and *G* as before to obtain *J* without constructing the back of the figure, draw *df* and from *H* a line parallel to it. This line will cut the line *ofJ* at the required point. This depends on the fact that all lines similarly situated on an isometric crystal are equal,

$od = of$; $oH = oJ$ and therefore df is parallel to HJ.

f. Checks on the accuracy of development will be found in the fact that the hemihedral apices *G*, *H*, *J*, *K* lie on the trigonal interaxes and should be in line with the center and a holohedral apex. The two methods of finding these apices should bring the same result.

g. As will be noticed most clearly in the tetrahedron, each face is inclined to its opposite, whence come the two terms used to designate these solids, tetrahedral or inclined hemihedrons. As can be seen on comparison with the other crystals of the group, the cuproid, the deltohedron and the tetrahedral hexoctahedron resemble a tetrahedron in which each face has been replaced by a three or six-sided pyramid. Consequently more or less than half the sides may be visible.

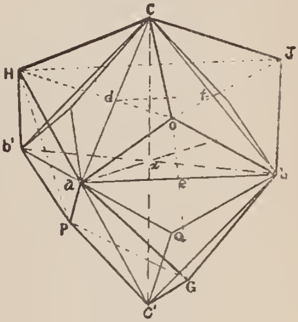

FIG. 5.

No attention is paid to the octahedron, cube, and rhombic dodecahedron as their construction is very simple.

The Trapezohedron and cuproid have already been fully explained in Fig. 3 and 4.

The Trigonal Trisoctahedron can be constructed by the method of Fig. 3, except that in this case the ratio of the intercepts cut by each plane is $m : 1 : 1$. To construct the deltohedron bisect *ac*, *ab*, *bc*, etc., and draw *odH*, *o e G*, *o f J*, etc. From *H*, the point where *O H* and *P H* intersect draw Hb^1, *Ha*, *HC* and by doing the same at *G* and *J* the figure is completed. *J* is most easily obtained by rule 8*e*.

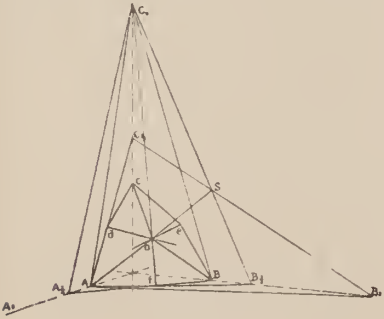

FIG. 6..

The Hexoctohedron, being more complicated, is constructed as in Fig. 6.

$AC_{\frac{3}{2}}B_3$ and $AB_{\frac{3}{2}}C_3$ have a line of intersection *A S*. Likewise $AB_{\frac{3}{2}}C_3$ and $BA_{\frac{3}{2}}C_3$ intersect in the line C_3f. The portion of the plane $AB_{\frac{3}{2}}C_3$ existing in the crystal is then *A o f*. The same method applies to the other faces, there being six possible combinations and six faces in each octant. The most rapid way to construct it is to draw the lines $AB\frac{3}{2}$, $AC\frac{3}{2}$, $BA\frac{3}{2}$, $BC\frac{3}{2}$, $CA\frac{3}{2}$, $CB\frac{3}{2}$ and from their points of intersection draw *do*, *fo*, *eo*. Having the point *O* draw *OA*, *OC*, *OB*, and the octant is complete.

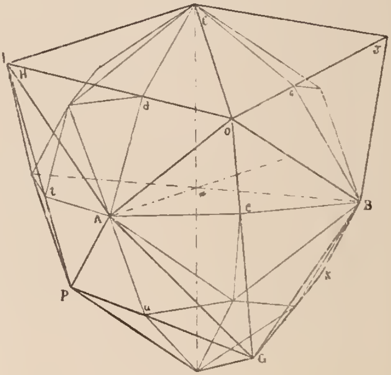

FIG. 7.

The plus hemihedron is developed in Fig. 7. *od*, *oe*, *Pt*, *Pu* are extended until they meet in the points *H* and *G*. *HA*, *HC*, *GA*, *GB* are then drawn. *J* is determined by rule 8*e* on a previous page. It will be noticed that in the figure, one face *B K G* of a rear octant is visible.

The Diploid. The hexoctahedron possesses two hemihedral forms and in this respect stands alone. No other isometric crystal enjoys this property. The pyritohedral form is constructed in a similar manner to the pyritohedron and as the latter is the more important that alone will be described.

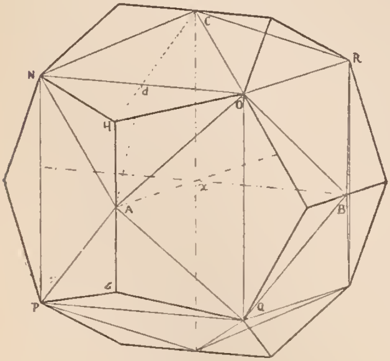

FIG. 8.

The Tetrahexahedron ($\infty : n : 1$), the limiting form of the hexoctahedron, is constructed in precisely the same way as the hexoctahedron, Fig. 6, except that $m = \infty$ and *Cd*, *Ad*, etc., are merely construction lines, and not to be inked in. The reason is shown in Fig. 8. *NCd*, *OCd*, lying in same plane, their line of intersection *Cd* is not drawn. Having completed the holohedral figure, select alternate planes in each octant to be preserved and, by suppressing the rest, produce the pyritohedron. If in octant *O* faces *OCN*, *OAQ*, *OBR* are preserved, all the rest are determined and the plus pyritohedron results. As every face is similarly extended it will be sufficient to give the method of extending one.

OAQ, *NAP* are both parallel to the vertical axis. Therefore their line of intersection at *A* will be parallel to it, and lies in the coördinate plane *CxA*. But *CdH* is the trace of *OCN* and the three planes possess a common point at *H*. As *O*, *N* are other common points, the three lines *GH*, *NH*, *OH* are determined. By pursuing the same method at the end of each main axis the entire figure is completed. It will be noticed that the opposite sides are parallel and half the faces are visible. If the drawing is accurate the lines passing through the main axes are bisected by them.

In drawing an actual crystal, composed of several forms, somewhat different methods must be used.

The Hexagonal System.—In this large system there is a vertical axis *C* and three lateral axes *a*, *a*, *a*, inclined 60° to each other and 90° to the vertical axis. The same discussion could be gone through as in the isometric system to get a general expression for the length and inclination of the axes. Dana as before gives the actual length and the angles to determine the apparent length of each. Prof. Frazier's method is much more easily understood. and is as follows:

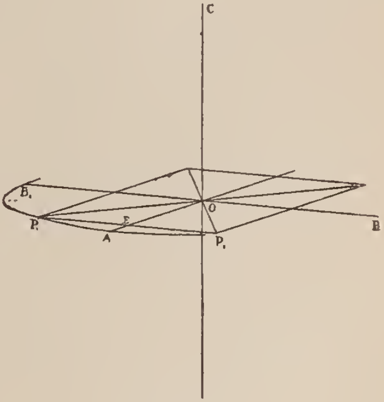

Fig. 9.

Having drawn our isometric axes *OA*, *OB*, *OC*, by any method whatever, bisect *OB* and OB_1 by lines pasallel to *OA*. Lay off on *OA* a distance $OE = (.866)\ OA$ and through that point draw a line PP_1 parallel to BB_1. Then in actual distance $PE = .5R$ and $OE = .866R$

All the forms under the hexagonal division are very easy of construction and we will only concern ourselves with the rhombohedral division. It is required of each student to draw a rhombohedron and scalenohedron with common basal edges, the vertical intercept of the latter being in some simple ratio to the former. In other words to draw a rhombohedron and a circumscribed scalenohedron.

1. This problem can be attached in two ways. The dihexagonal pyramid could be drawn and the scalenohedron devoloped from it by suppressing the alternate sectants. A rhombohedron could then easily be constructed by drawing lines parallel to the basal edges of the scalenohedron as shown in Fig. 11. But it would be no easy matter to draw such a scalenohedron that the inscribed rhombohedron would have a vertical axis in some simple ratio to the former.

2. For this reason it is preferable to develope the rhombohedron from the hexagonal pyramid, and by lengthening the vertical axis produce any scalenohedron desired.

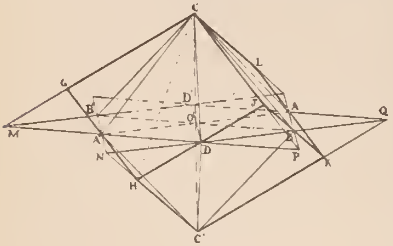

FIG. 10.

Dana's method, page 468, is a very quick way, but the rhombohedron produced is of the second order, and if lengthened into a scalenohedron, one face would be found to lie in each sectant, a theoretical difficulty which can be avoided by calling his axes the interaxes, and drawing another set bisecting the basal edges as in Fig. 11. This does not employ the hexagonal pyramid, however, and to show the mathematical relation between the two Fig. 10 is given.

Having drawn our axes, AA', BB', DO', CC', connect the ends and we have the hexagonal pyramid of the first order. Choose alternate planes to be preserved, as: $CA'D$, CAB, $C'DB$, etc. Extend the traces of each of these faces on the basal plane. MP, AP intersect at P, making it a point common to $CA'D$, CAB and CP is, therefore, their line of intersection. In the same way CM is the intersection of $CA'D$, $CB'D'$. $C'N$ that of $C'A'B'$, $C'BD$ and $C'Q$ that of $C'DB$, $C'BA$.

But $MO = OQ$ and CM is parallel to $C'Q$. Therefore the intersection of $CA'D$ and CBD passing through D is parallel to them also. In this way it may be shown that *GH* is parallel to *CJ* and *JK* to *CL*. The proof of each step is not given fully but indicated sufficiently for it to be followed out. These steps may be summarized in a rule.

RULE.—Extend the basal traces till they intersect at *M*, *N*, *P*, *Q*. Draw *CM*, *C′N*, *CP*, *C′Q* and through the ends of the axes draw lines parallel to those already found. By so doing we have determined the four boundaries of each plane. The completed drawing, free from construction lines, is shown in Fig. 11.

The rhombohedron having the symbol —*M*, the scalenphedron will be —M^2 and is obtained by preserving the same basal edges and lengthening the vertical axis to twice its former value.

In this case the figure is a cube, a rhombohedron which does not exist in nature, but which shows how a cube may be held as a rhombohedron.

It will be noticed that there are only three sets of parallel lines, a determination of one from each set enabling us to draw the rhombohedron. If the work is accurate the basal edges will be bisected by the lateral axes.

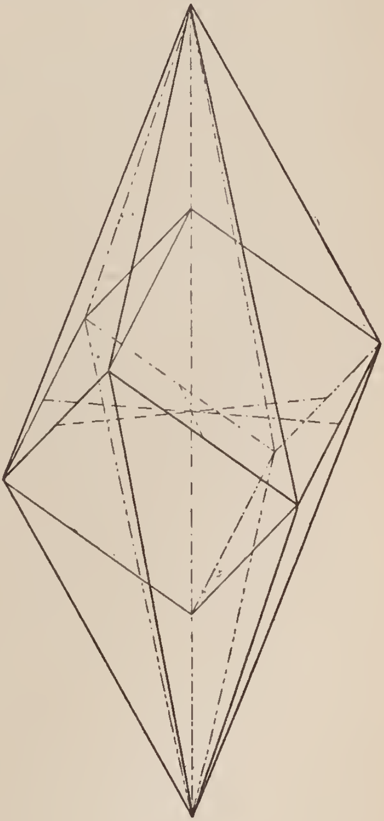

FIG. 11.

Another method of obtaining the point *H* is to draw *CH* bisecting *A′D*. Where it cuts *C′N* the point *H* will be located as *H* is then a point common to three planes of the rhombohedron.

JOSEPH BARRELL, '92.

The first man to intelligently study and classify limes and cements was the Frenchman Vicat who carried on his researches in the early part of the century, and, as a result of his labors, the classification he adopted is practically that which is accepted to-day.

From Prof. W. C. Unwin's interesting and valuable work on the "Testing of the Materials of Construction," the following is taken.

Cementing materials ordinarily used are classified thus:

1. Rich or fat limes.
2. Poor limes.
3. Hydraulic limes.
4. Hydraulic cements.

1. Fat limes are produced by the calcination of nearly pure limestone (from 90 to 97%), and consist of lime nearly free from other ingredients. It is the ordinary lime of commerce, and is manufactured by almost every farmer around the Bethlehems; the kilns dotting the hill-sides and road-sides in every direction.

This kind of lime slakes violently when mixed with water, accompanied by a rapid rise of temperature.

It has been claimed, but how much truth there is in the statement is not known, that vessels on Lake Erie, transporting lime from Kelly's Island to the mainland, have burned up when through any accident a large amount of water was brought into contact with the lime.

The lime, when setting, absorbs carbonic acid gas from the air, forming, in the course of time, the carbonate of lime.

2. Poor limes contain from 10 to 40% of sand or inert matter; they slake less violently, and make a very weak and slow setting mortar.

3. Hydraulic limes and cements contain ingredients capable of combining and hardening, apart from any absorption of carbonic acid gas from the air. They will, therefore, set under water. The hydraulic *limes* contain a large amount of pure lime, so that they slake. But they also contain clay, silica, or other ingredients capable of producing chemical action in the presence of water.

This action results in the setting of the lime, which hardens and becomes insoluble. Feeble hydraulic limes make mortar, which hardens enough to resist a finger-nail in a month.

4. Artificial hydraulic cements are mixtures of lime and clay, in proportions suitable to produce eminent setting or hydraulic qualities.

Such cement hardly slakes at all, but sets with great rapidity, becoming, in the course of time, extremely hard.

Portland cement may be produced from a variety of natural rocks, but broadly speaking, it consist of 72%–79% of chalk and 28%-21% of clay.

Originally chalk and clay were ground together with a large volume of water in a fluid grout, but now it is found that 35% of water is not only economical, but prevents the segregation of materials which takes place in fluid grout.

To sum up this classification, consider *limes* as divided into three classes, rich or fat, poor, and hydraulic. The difference between these classes and the Hydraulic cement is, the cement contains a larger proportion of silica, aluminum, magnesia, etc., than does any member of the group of limes.

The members of the lime group absorb water according as they vary, from the common lime, which swells up from 2-3.5 times its original volume, to the hydraulic lime which increases in bulk from 1.76-2.5 times its original volume. Herein lies their defect for most purposes. The hydraulic cements do not swell when manufactured properly; the test for checking and cracking, due to the hydration of the lime or magnesia, being made to determine this very point.

Michaelis states that the hydraulicity of a cement is due to the silica, alumina, and iron, and that in a good cement, the sum of these should be about one-third of the total weight, the rest being chiefly lime.

The calcination removes the carbonic acid gas and water, and leads to the formation of calcium silicate, calcium ferrate and calcium aluminate and the hardening of the mixture, when water is added, depends probably on the formation of double hydrated silicates. From a clipping from an engineering paper is taken the following:

"In an article on the hardening or setting of Portland cement mortars the *Chemiker-Zeitung* directs attention to some recent experiments made by Herr Schiffner. Too much water, as well as too small a quantity in mixing the mortar prevents proper hardening. Portland cement mortar takes into chemical combination a definite quantity of water, and the highest degree of hardness is obtained when this chemical absorption is complete. The formation of hydrosilicates, due to this absorption, is a gradual process. In a pure cement mortar the percentages of chemically combined water are—

	PER CENT.
After mixing	0.99
" 4 hours	1.41
" 20 "	2.29
" 3 days	5.62
" 7 "	7.58
" 14 "	7.96
" 18 "	8.45
" 21 "	8.91
" 28 "	10.52
" 56 "	11.60

Schiffner's experiments further showed that the cement mortar, kept moist twenty-four hours after mixing, and then placed under water, improves in hardness with the duration of its submersion. In the trials under consideration, the longest period of submersion was twenty-seven days. If, after mixing, the mortar is not kept moist, it becomes brittle and crumbles. In the cement briquettes kept under water for twenty-seven days, Schiffner found from 10 to 11 per cent. water and from 1 to 1½ per cent. carbonic acid; in the briquettes kept under water for three days there was found from 6 to 7 per cent. water and from 1½ to 2½ per cent. carbonic acid. In dry briquettes the combined water amounted to only 4 per cent., while the carbonic acid figured up from 6 to 7 per cent. It is concluded, therefore, that to secure the best results in using cement mortar it must not be given opportunity to become dry during the first few days after mixing."

At Bethlehem is found the ordinary blue limestone, which gradually merges into an impure limestone when Coplay is reached. At Coplay the rock contains about 75 per cent. of lime, 2 per cent. of magnesia, 5 per cent. of silica, and 8 per cent. of alumnia and iron, a rock suitable for a natural cement. The following notes relate to the manufacture of cement, as it is carried on in this Coplay or Lehigh district.

The cement made from this rock is a Rosendale or Portland, according to the method of treatment.

To produce a Rosendale cement, the rock is put into an ordinary perpetual kiln, and for fuel buckwheat coal is used, about one foot of rock to fourteen or fifteen shovels of coal. The burning is very light and leaves about 8 per cent. of the carbonate in the cement. The burned rock is crushed in what looks like an old-fashioned coffee mill, then ground by millstones and is ready for the market.

It may be well to outline the process of the manufacture of the Portland cement, to make it clearer.

The rock is taken from the quarries by the ordinary process of drilling and blasting; is crushed, ground between millstones, wet to form a stiff mud, dried, burned, reground between millstones, seasoned, and is ready for the market.

In the quarry, blasts are made twice a week, enough rock being loosened to keep the works in operation the intervening time. This is done in order that any variation in the rock, shown by chemical analysis of each blast, may be confined to that quantity of material. Gen. Gilmore gives as a reason, "All sedimentary rocks are, for marked variations in their lithological character within small limits, owing to local causes affecting deposition."

Then should a certain yield of rock run short in lime, the chemist can specify how much is to be added to bring it up to the standard. From the quarry, the rock is taken to a coarse crusher which breaks it up into pieces weighing about four ounces; it is next run through a finer crusher, which breaks it into pieces that would probably pass through a half inch ring. This double crushing prepares the rock for the millstones. In this simple form of grinding mill, the top stone is stationary, and rests on the bottom one called the "runner." The fine crushed rock passes through a hole in the top stone to the grinding surfaces, and is ready for the pugmill or mixing vat, looking like a fine gray powder or flour. The millstones come from York State, Lancaster County, Pa., and from the Blue Mountains.

There are two methods of mixing the ground rock with water. One is a continuous process, mixing the dry powder with hot water and slowly forcing it through an inclined tube containing a revolving screw which mixes the water and powder into a stiff mud. The other method uses cold water, the mixing taking place in an open rectangular box with a hinged bottom. In the box two cast iron drums revolve in opposite directions. In the drums are inserted long teeth or spikes, which interlock as the drums revolve, but do not come in contact. About 600 lbs. of the dry rock is admitted at each mixing, which lasts about five minutes, and enough water is thrown in to bring the mass to the consistency of good putty. When the operator judges the mixing is completed, he drops the mud through the bottom of the box to the floor of the room below. The mud is a dull drab in color and may be made into bricks in either of two ways.

It may be run through a brick machine, such as is used for the manufacture of ordinary building bricks, the bricks being conveyed by a broad belt to another room for further treatment. But it is claimed that the brick machine compacts the mud to such an extent, that either the outside of the brick must be over-burned in the kiln to produce a proper burning on the inside, or else the inside will be under-burned in order to burn the outside properly. Those who do not favor this method take the mud as it comes from the pugmill and spread it over a large wooden floor, by means of shovels, to a depth of two and one-quarter inches. It is then cut into bricks, two and one-quarter by four by six inches, and boys with shovels pass rapidly along and turn the bricks upon edge.

The firm using the brick machine claims that seven men, with one machine, can do twenty-five men's work; while another firm claims that to spread the mud on the floor for 10,000 bricks is forty horse power cheaper, besides being better, for reasons already given, to use men and boys in the manufacture. In the first case the number of horse power necessary to run the brick machine for a certain number of bricks is wanting; in the second case the number of workmen necessary to make 10,000 bricks is not known. Hence no conclusions as to economy can be drawn. When the bricks are formed on the floor they stand for ten hours, and are then piled around long lines of steam pipe, fed by the exhaust steam from the engines running the crushers, stone mills, and conveyors. At the end of twenty-four hours the bricks are dry enough for the kilns.

If a brick machine is used, they are taken from the belt conveyor, before mentioned, and piled on pallets or iron frames; these pallets are placed on iron cars, each car holding five hundred bricks; the cars are then run into long brick ovens or drying channels which are heated by the waste gases from the kilns. They dry for twenty-four hours and are ready to be burned.

Before proceeding to a description of the burning it may be well to mention one point. A company at Coplay adds lightly burned uncrushed Rosendale rock to the quarried rock for the Portland cement before it passes to the crushers, this combination of Rosendale cement and new rock running through the crusher and mills, and is made as before into mud and then into bricks. The reason given for adding the Rosendale is, that the ground rock alone will not form a brick which will stick when mixed with water. The bricks, as they are made on the floor, contain nearly 50 per cent. of water, as can be shown. About 600 pounds and 4-5 buckets of water are used in the mixing box, giving about 300 pounds of water to 600 pounds of ground rock. Each brick weighs about four pounds as it is made, and loses, first at the steam pipes about four ounces of water, and later on the remainder of the water of mixing. A process which worked very well at one time, employed pitch in the mixing of the ground rock, preparatory to burning. The pitchy mass was moulded by machinery into nodules, about the size and shape of butternuts. The pitch was entirely removed and caused a quicker and more thorough burning. But the pitch producers raised prices and killed the scheme. The bricks, by whatever process made, are next subjected to the burning in the kiln.

The kiln employed is intermittent, and, unlike the one used to produce Rosendale, is taller and is charged, not by throwing the material in through the top, but through openings in the sides. In a perpetual kiln the layers of rock and fuel do not settle evenly, but may compact in one spot and grow more open in another, aiding and retarding the burning. The kilns are made of different capacities, the following description and figures applying to a forty ton kiln. Such a kiln is circular, all horizontal sections above the grate bars being circles. At about one-third the height, it has one opening or door, which is used to charge the lower portion of the kiln, and is then closed with fire brick; and, a second opening, about thirty feet from the bottom, closed with a heavy sheet iron door. The kiln is lined with fire brick up to the middle of this second opening, or door, the heat not being sufficient to require its use above this point.

A central vertical section of the kiln would show a form similar to the ordinary blast furnace. Starting at the grate bars, it flares to the widest point of the boshes and then diminishes to the top. The dimensions are approximate. The total height, from the floor beneath the grate bars is forty feet. The grate bars, three feet from the floor, are made of rails which are not fixed but can be drawn, allowing the charge to drop to the floor. The boshes at the widest part are twelve feet in diameter and eight feet from the floor. The shaft of the kiln tapers from twelve feet to five feet at the top, which is entirely open. The space below the grate bars is rectangular, four feet wide and running back six feet. To prepare the kiln for charging, one-third of a cord of wood, together with some cotton waste soaked in oil, is placed on the grate bars. The fuel used is coke and is so regulated in quantity that there are about two inches of coke to four inches of brick, the bricks being placed on the two and one-quarter by six inch side. Coke furnishes a more even and greater heat.

The charging proceeds from the lower opening. The coke is passed in in buckets holding about seventeen pounds, and is carefully spread out in an even layer. The first layer requires seven buckets of coke, the next eight, increasing to twelve or thirteen at the widest part of the boshes. From this point to the top, nine buckets are used to each layer of brick. The bricks are placed in position by hand, carefully and evenly. When the filling reaches the first arch, the arch is bricked up. The materials are then passed in from the top opening and placed as before, until about thirty feet of material has been filled in. A variation may take place in the amount of fuel used, for two reasons: more may be added to hasten the burning, or if too much water has been added at the pugmill, more fuel must be used; if too small an amount of water, less fuel. The variation in the amount of fuel is made at the discretion of the man in charge of the kilns, whose experience tells him whether to increase or decrease the amount of fuel, but occasionally he misses it and "botches a kiln."

The kiln, when charged, contains 40,000 bricks containing about 47 per cent. of water, and something like four and one-half tons of coke.

Perhaps the following abstract from "The Portland Cement Industry in the U. S., (a work issued by the American Cement Company) will serve to make clear the reason for this preparatory process of grinding, and mixing, and forming of bricks. "This cement (Portland) differs from the natural light-burned hydraulic cement, in the fact that it is an artificial product, wherein the proportions of lime, silica and alumina are combined in uniform proportions, and wherein the material that is calcined in a kiln is a new rock or stone, artificially produced by the mechanical mixing of the clay and lime, or of the natural rocks composing it, in finely divided particles with water, so that each of the fine particles of alumina and silica and lime is in close mechanical combination with the other particles, and the whole new rock, that is placed in the kiln in the shape of bricks, eggs, or balls, for the purpose of calcination, is mechanically fitted to be best acted upon by the high heat of the kiln, in order that the chemical action necessary for the production of the highest grade cement can take place under the most favorable circumstances."

The fire is started by means of the cotton waste and cord wood and burns for three days, under a natural draught. Then the top arch is opened, and about three barrows of light yellow unburned material is removed. The charge then stands for ten hours, when the grate bars are drawn, dropping the clinker as it is now called, to the floor. The bricks which went into the kiln have, by this burning process, undergone a change, and now contain about 23 per cent. silica, 12 per cent. alumina and iron, 60 per cent. lime, and 4 per cent. of magnesia and sulphuric acid. The clinker, as it comes from the kiln, consists of three parts.

That which will yield a first grade Portland, is dark in color and heavy, and looks somewhat vitreous; a second part, which is lighter in color and weight, and not so hard, and a third part which is the fine powder and dust, and is added to the Rosendale cement.

The total yield is forty tons, of which thirty-eight tons are first grade Portland, and two tons second grade Portland and Rosendale.

The separation of the three parts is effected by men taking up the clinker on forks having tines one and one-half inches apart, removing from the fork by hand any clinker which is light in color, and throwing what the fork retains into barrows or carts, to be taken to the stone mills. The remainder is shoveled against a screen of one-half inch mesh, the rejected part constituting a second grade Portland clinker; the part passing the screen being ground in with the Rosendale.

The Portland clinker is now passed through the mill stones in the same manner as before the burning. Another form of mill was seen in operation at the American Cement Company's works at Egypt, which depends on centrifugal force. An iron ball, weighing about 500 pounds, is hung by a ball and socket joint in a heavy iron casing. The rotation of the vertical driving shaft throws the ball against the casing, exerting a pressure as it flies around, varying with the speed of the rotation. The grinding surface being between the casing and the rotating ball.

The ground cement is elevated to the bolting machine, which is a frame in the form of a cylinder having an outer covering or screen of 2500 meshes per square inch and a coarser inner lining near the outer which serves to prevent the weight of the cement from coming suddenly on the outer screen. The bolter is inclined and has radial rods with sliding weights called knockers, which, as the machine revolves slowly, knock against the bottom of the frame, shaking the cement and preventing it from clogging up the meshes. The cement is fed at the upper end, and passes from the inner to the outer screen; that which is sufficiently fine passing through both screens, and is conveyed to the storage bins. The rejected part runs out at the lower end, between the two screens, and is returned to the mill stones. The full process, from the time the rock leaves the quarry to the bolting occupies about seven days.

The rate of grinding will affect the value of a cement when considered economically,

Prof. Unwin states that "The clinker must be ground so fine that the cement particles may expose a maximum surface at which chemical action may occur, and not too large to fill the smallest interspaces in the sand, with which the cement is mixed in use."

This fineness can be attained by running the mill stones slower, which adds to the cost of manufacture, or by using a soft underburned rock, which is cheaper and produces an inferior cement, or by bolting the cement, returning the rejected part to be reground, which also adds to the cost. If a clinker be soft, a certain rate of grinding may produce cement weighing 100 pounds per bushel; if the same rock had been burned into a harder clinker the cement might have weighed 120 pounds per bushel; so that generally a heavier cement indicates a more thorough burning. But on the other hand there is an offset, in that slow grinding of a hard clinker, which adds to the cost of manufacture, will produce a light weight cement as will also a soft underburned clinker.

The American Society of Civil Engineers states that fineness is no sure indication of the value of a cement, but that the best grades of Portland will leave but from 5 to 10 per cent. on a sieve of 2500 meshes per square inch.

This new Portland is at first a "green" cement, the seasoning or standing in the bins allowing any free lime or magnesia to slake; it also decreases the time of setting. Some manufacturers claim that one and one-half per cent. of magnesia in a cement is dangerous. It is also stated that two per cent. of sulphur will ruin a cement. A green Portland, when made into neat briquettes for testing, while setting, will not fall below the top of the moulds when cut off, nor will water flush to the top. The writer had a sample of freshly ground Portland cement, which was taken from the moulds inside of five minutes, and did not require careful handling. Rosendale cements, on the other hand, deteriorate with age and grow weaker It is for this reason that nearly all engineers specify, that Rosendale cement shall be "fresh ground."

A barrel of Portland generally weighs 400 or 380 pounds of cement, net, and prices range from $3.00 to $4.00 per barrel of 380 pounds.

Mr. R. W. Lesley of the American Cement Co., furnished the writer these figures. "There are about 7,000,000 barrels of natural cement made in the United States per annum. The output of Portland cement in this country will not exceed 250,000 to 300,000 barrels per year, made principally in two districts, the Lehigh district and the Syracuse, N. Y., district. The imports of Portland cement for last year (1891) were stated to be 3,000,000 barrels, but this was an excess import, as nearly one-half million barrels of cement were in stock on the first of January, and which are not yet taken up into consumption.

F. A. COLEMAN, '92.

ALUMINIUM AND DIAMONDS.

(FROM THE GERMAN OF A. JAROLIMEK IN "DER STEIN DER WEISEN.")

When, in 1875, I investigated the question why no regular crystals are produced when water is frozen, while the falling snow reaches the earth in beautiful, hexagonal crystals, I arrived at the conjecture that this might have some connection with the phenomenon which separates water from other bodies; i.e., that it attains its maximum density not at its freezing point but at 4° Centigrade.

Since the resulting ice has a smaller density than water, the freezing process goes on under different conditions than when a specifically heavier body crystallizes out of a specifically lighter solution or liquid.

Two considerations must be noted,

1. The immediate influence of gravitation on the molecules of the body, and

2. The influence of the density of the liquid on each of the moving, crystallizing particles.

For the first, it is clear that the tension set up by gravitation between the molecules of the body must cease, if the particles are to follow the crystallizing forces; and that this is so is evidenced by the observations that freely falling drops crystallize in perfect crystals, and even the drops of water sticking to the window-pane, their weight being partly neutralized by adhesion, form finer crystals than water resting in an open vessel.

I remarked in 1875 that I should like to make the experiment of dropping molten pig-iron down the 1000 metres-deep Adalbert shaft, at Przibram, in order to observe if the crystallization of the mass was influenced thereby. That this thought was not entirely illusory has been evidenced by a communication of Fletcher's in *Nature* of July 28, 1887, stating that in a piece of meteoric iron which fell in Australia in 1884, graphite was found in the crystal form of the diamond.

However, I believe that the principal influence should be ascribed to the second consideration; namely, *the relation between the density of the crystals being formed and the density of their mother-liquor*.

All crystals form most perfectly when they separate out of solutions, consequently out of a medium of lower density.

However, on the freezing of liquids we only see the more perfect crystals form when the substance contracts considerably in crystallizing, that is, when the density of the crystals somewhat exceeds that of the mother-liquor, as, for example, with zinc. Sulphur crystallizes by freezing in monoclinic crystals with a specific gravity of 1.96; but out of solutions it is rhombic, with a specific gravity of 2.05.

Even in 1857 Wöhler and Deville succeeded in producing boron (specific gravity 2.68) out of its solution in aluminium (specific gravity 2.67) in perfect crystals (boron diamonds); but they could not obtain carbon diamonds (specific gravity 3.5) from the carbon dissolved in iron (specific gravity 7.84), which failure I ascribe to the difference in the density of the two latter bodies. The question is, then, what mixture of metals may we expect to have the property of dissolving carbon and to yield it again in regular crystals.

According to my previous remarks, the specific gravity of this mixture must not exceed 3.5, and, therefore, the "light" metals, before all, come to mind.

Since it proved practicable to obtain boron-diamonds from the solution of boron in aluminum, there is not a doubt that many attempts have been made to make carbon diamonds in similar ways. The correct way, however, has not yet been found, and I will now show how I attempt to discover it.

Mendeléeff and Lothar Meyer have arranged the elements in a natural system, according to the Periodic Law, which states that "The properties of the elements are periodic functions of their atomic weights."

If the part of the system containing the elements under consideration be taken by itself, it would be as follows:

FAMILY: Series:	II.	III.	IV.
1	*Be* = 9.08	*B* = 10.90	*C* = 11.97
2	*Mg* = 23.94	*Al* = 27:04	*Si* = 28.00
3	*Ca* = 39.91	*Sc* = 43.97	*Ti* = 50.25

The specific gravities are

Be = 2.10	*B* = 2.68	*C* = 3.55
Mg = 1.75	*Al* = 2.67	*Si* = 2.49
Ca = 1.58		*Ti* = 5.28

From this table it is first seen that the element standing next to boron-(aluminium) is the one by whose agency the boron-diamonds were obtained. By analogy it might then be conjectured that crystals of beryllium should be obtained from a solution in magnesium, and crystals of carbon from a solution in silicon.

Yet there exists here a very important difference. Boron is not a metal, but a body very similar to carbon; this fact may considerably favor its crystallization from a molten metal. Beryllium and magnesium, on the other hand, are both metals, while carbon and silicon are both non-metals.

That beryllium, under right conditions, could crystallize out of an alloy with the specifically lighter magnesium, is easily possible; as, for example, lead (specific gravity 11.37) likewise separates in a pure state from an alloy with silver (specific gravity 10.50). With this, however, we are not concerned, but with the crystallization of carbon out of a suitable solution.

Now, the element silicon, coming next to carbon in the table, is only fusible in the crystallized form and at a high temperature. It has, like carbon, three modifications, appearing as amorphous powder, as a graphitoidal, incombustible mass, and in octahedral crystals similar to the diamond. In silicon, as such, carbon could never be dissolved; on the contrary, it has been found that the combined carbon in steel partly is expelled by silicon, whereas, on the other hand, tungsten, chromium, and especially manganese facilitate the solution of carbon in iron. Even the element next after silicon in Family IV, titanium, which occurs frequently in silicates and in most iron ores, is a very infusible powder and offers no suitability for producing carbon crystals; besides, it belongs to the list of metals.

Therefore, carbon does not find elements suitable for its solution and crystallization among its next neighbors, as boron does, and on this account it becomes necessary to search farther.

The question may then be raised, whether carbon might not, like boron, be produced in crystals from solution in aluminium, or from magnesium which is even specifically lighter than silicon. Such experiments have already been made, and with negative results. Aluminium is, indeed, obtained from the Cowles and Mabery electric furnace as a carboniferous metal, but the carbon is not really in chemical combination as an aluminium carburet. Indeed, experiment has shown that aluminium expels carbon from its solution in iron. If iron at a high white heat is intentionally saturated with carbon (it takes up six per cent.), and then 30 per cent. of aluminium is added, scales of graphite are so abundantly separated out by this addition that the fluidity of the mass is greatly interfered with and it becomes so thick and pasty that it will hardly flow, although the melting point of the alloy has been lowered by the large addition of aluminium (communication to the Berlin General Electric Co.). If, with a similar proportion of carbon, the addition of aluminium is only 15 per cent., then the six per cent. of carbon will still remain in solution at a high white heat, but as soon as the temperature begins to fall the graphite begins to mount to the surface in considerable quantity. With ordinary percentages of carbon the separation of carbon also takes place, but only at the moment of setting. It is, therefore, apparent that aluminium does not enter into combination with carbon, but, on the contrary, influences the expulsion of the latter from the mass in which it occurs.

How Magnesium behaves in this relation I do not know. It is further from carbon in the natural classification of the elements than aluminium is, yet it is indeed possible that it would form a combination with carbon easier than aluminium, as would be indicated by the relations of its atomic weight. For, while the atomic weights of aluminium and carbon (27.04 and 11.97) show no harmonic relations, those of magnesium and carbon (23.94 and 11.97) show the simplest relation of 2 to 1. However, magnesium is much less fixed than aluminium, passing off as vapor at a high temperature, making its use very difficult.

In reality, experiments on the relations of carbon in its combinations with metals have so far been made only with iron and manganese (perhaps also chromium and tungsten), which, as already shown, unite chemically with carbon, and I beg to be allowed to briefly describe the facts as so far known.

It was Tonner who first, over twenty years ago, observed that of all kinds of iron spiegeleisen showed the surest signs of being a chemical compound, since it is purely crystalline and by its properties very far removed from the almost infusible, pure iron. Its composition corresponds to Fe^4C (quadri-carburet). All attempts to produce other combinations of iron and carbon have been fruitless. Pig iron is a solution of pure iron in spiegeleisen; grey pig iron contains besides this graphite.

The electro-positive elements occurring in iron can in part replace it in its combination with carbon, which is particularly the case with manganese. But even carbon has also its substitutes in the never-absent electro-negative ingredients silicon, sulphur and phosphorus; yet such substitutions have been shown to be complete only in regard to silicon. The fact that silicon forms a chemical combination with iron has found a practical application in the manufacture of silicon-iron and silicon-ferro-manganese on a large scale.

The addition of such silicon alloys during steel melting, assists in the production of denser steel castings and has just the same effect as the addition of a small proportion (0.05 to 0.10 per cent.) of aluminium to the iron.

From the preceding observations it appears as certain that silicon and carbon are able to exclude and expel each other from their combinations with iron.

These facts are of importance for my researches, and I may add to them the important observation that silicon decreases the susceptibility to hardening since it hinders the formation of iron carburet crystals and tends to separate out carbon in the form of graphite. Silicon (which is, indeed, not found in nature in the free state, like carbon) thus appears to be a more closely related element to iron. Silicon-iron is even more fusible than steel, and this is yet another reason why carbon separates out first from a cooling mass of liquid iron which contains much silicon and carbon, when it has cooled so far that it cannot hold all of these any longer in solution. After considerable carbon separates out, the silicon still remains in solution.

We, therefore, possess in silicon a reagent wherewith carbon can be separated out of its combination with iron (or manganese).

Ordinary spiegeleisen contains, along with 5 to 6 per cent. of carbon, only a little silicon; silicon-iron, on the other, contains only little carbon; and even in the so-called silicon ferro-manganese, with 73 per cent. of manganese, 17 of iron, and 8 of silicon, there is contained only 2 per cent. of carbon.

Quite similar to these are the relations in the case of aluminium. Commercial aluminium contained at first 7 per cent. of iron and 5 per cent. of silicon, but no carbon. At present, commercial aluminium shows 1.4 to 5 per cent. of iron and 0.12 to 0.70 per cent. of silicon, and yet no carbon, so that the latter appears to be entirely excluded from aluminium by the silicon.

From all this it may be concluded that carbon separates out of metallic alloys quite easily, even too easily, and, therefore, mostly as graphite; and since this separation is favored just as well by the presence of aluminium as by that of silicon, the use of the latter as the reagent for separation is not only unnecessary, but must, if practicable, be avoided, that the carbon in the alloy used may remain in solution as long as possible.

For this purpose, it seems that iron is the only suitable metal. Its relations to carbon are (according to Reiser) as follows: The carbon is contained as carbide not only in molton iron and steel, but even in these when already set, if still highly heated, and is separated out (as graphite) only on further cooling. During tempering, that is in the preliminary heating to about 700° C., the graphite dissolves up again in the steel, so that it may be considered that the setting free of the carbon takes place in the steel, when slowly cooled, at about 600° C. But the formation of carbon crystals in iron already set can, naturally, not take place. It is, therefore, of first importance to consider the following conditions:

1. That the steel must be alloyed with the light metals until brought into that condition that it remains fluid at temperatures of 500° to 600° C., that is, down to the point of decomposition of the iron carbide.

2. This second point I have already considered: the specific gravity of the alloy must not exceed the value 3.5.

As further conditions I would probably add:

3. The iron used as well as the light metal should be as free as possible from silicon.

4. If the alloy still lacks the power of retaining the carbon long enough in solution, then manganese may be added, which retains the carbon better in combination.

After having described all the conditions, I formulate my propositions as follows:

I. Carboniferous iron is alloyed with any of the light metals, so that the specific gravity of the mixture does not exceed 3.5, and the melting point of the alloy falls to about 500° to 600° C.

The use of magnesium, for instance, with specific gravity of 1.73, would require three parts of magnesium to be taken for one part of iron; of aluminium, with specific gravity 2.67, it would require seven parts to one part of iron. According to several investigations, alloys of aluminium and iron or of aluminium, magnesium and iron are easily produced, which not only in regard to specific gravity but also in regard to melting point come up to the requirements laid down.

Since aluminium melts at 700°[*] and magnesium at 400°, the manufacture of easily fusible alloys is so much the easier, since alloys usually possess a melting point lower than would be given for the mixture by calculation. Experiment has even shown that the addition of only 0.1 per cent. of aluminium to cast iron lowers its melting point 400° to 500°[†]. Further, aluminium mixed with iron at a high temperature induces a re-arrangement of the molecules, by which latent heat is set free. In order to cast wrought iron into moulds it must be heated far above its melting point (1600°) in order to avoid its setting during pouring. But, if a small quantity of aluminium is added just as it reaches the melting point, a large quantity of heat seems suddenly to be set free, the temperature rises visibly and the iron becomes very fluid.[‡] Metal which is already nearly set is remarkably vivified by the addition of 1 per cent. aluminium. It is hereby apparant that aluminium alloys well with iron. There have been described on the one hand alloys of iron with 30 per cent. of aluminium, while on the other hand aluminium is found with 7.5 per cent of iron; to which may be added that alloys with 15 per cent. of iron can be made by mixing the other two alloys just mentioned in the proper proportions.

Comparative experiments would soon show to what extent pure silicon-free aluminium can be alloyed with iron without the latter losing its carbon. If an addition of only 8 to 10 per cent. of iron to aluminium is permissible, even this may be found practicable.

II. Since the so-called spiegeleisen, saturated with 6 per cent. of carbon, immediately expels its carbon when aluminium is added to it, it follows that only iron or steel of normal carbon content (1 to 2 per cent.) can be used, or, finally, the aid of manganese may be invoked to keep the carbon in solution. Manganese holds carbon stronger than iron does, on which account it plays an important part in the spiegeleisen added during the manufacture of steel. Manganese is, however, by itself and in its combinations with carbon and silicon, not so easily fusible as iron, and can, therefore, be used only in limited quantities in our investigations.

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[*] The best determinations make it 625°.—Translator.

[†] This statement was made a few years ago, but has since been proven fallacious. The melting point is not lowered more than 25° at most. —Translator.

[‡] It is probable that the temperature is not sensibly increased, the increased fluidity and apparent greater brightness being due to other causes too obscure to explain in this article.—Translator.

If it be concluded that the aluminium must only contain 10 per cent. of iron, and that the latter possesses a content of only 1.5 per cent. of carbon, the alloy would then contain

90.00 per cent. aluminium.
9.85 per cent. iron.
0.15 per cent. carbon.

Its specific gravity would be about 3.18, which small figure might even be found to exceed its actual gravity.

In a kilogramme of this alloy there is 1.5 grammes of carbon, = 7 carats, enough to render possible the formation of small crystals.

III. The iron used as well as the aluminium should be as free as possible from silicon. Only if circumstances show the necessity of hastening the separation of the carbon should a silicious aluminium be used.

IV. The alloy is well-mixed at the necessary temperature, and then the heat is to be very slowly lowered. At the critical point where the iron carburet begins to precipitate (about 600°), the formation of crystals would commence (if my suppositions are correct), and this phase must naturally be passed through very slowly, also the influence of air must be carefully guarded against, not only in the melting, but in the cooling, and the temperature must always be well regulated.

V. If small crystals are obtained, they can be introduced into a fresh carbon alloy in order to increase their volume, if possible.

In this connection I am not unaware that recently an Englishman, named Parson, has succeeded under the following conditions in making real diamond dust:

In order to get carbon of especial hardness he fills a very strong steel cylinder, in which is placed a carbon rod, with layers of burned lime, argentiferous sand, clay, and carbon dust. The whole is strongly compressed by hydraulic pressure, and a strong electric current passed through it. After the operation a gray powder was found on the carbon rod which was harder than emory, and scratched the diamond. It was diamond dust.

If this communication is correct, we have here the formation of carbon crystals by another method than the one I have proposed. Yet, if a reduction of the material mixed with the carbon has taken place under these conditions of high pressure, high temperature, and a strong electric current, it may be that alloys have been formed during the operation of a composition analogous to those proposed by me, and that the carbon had crystallized out of them. Since, however, the diamond dust was found lying on the carbon rod like ice crystals on the window-pane, it would appear that the above described experiment is not suited to lead the way to the formation of larger carbon crystals.

It may well be that this end will be soonest reached by the application of the pure metals according to my propositions.

(*Translated by Joseph W. Richards.*)

THE ST. PAULO RAILWAY, BRAZIL.

As a field for engineering, Brazil is coming more and more to the front, and it may therefore be of interest to give a short sketch of the railway from Santos to St. Paulo, over the Serra do Mar, showing some of the difficulties to be encountered and the manner in which they have been overcome.

The engineering plans were first laid down by Sir Joseph Van Lees, and afterward carried out by Mr. Daniel M. Fox as resident engineer.

The road is forty-three miles long and requires about two hours and a half to make the trip. The ascent of the Serra is well worth a few words of description. The train is separated into sections of three cars each and a brake van. The engine is left, and the cars drawn by cable up the Serra, in four stages, from an elevation of 68 feet on the level to 2625 feet at the top. These cables are of Birmingham manufacture, 4 inches in circumference, consisting of 6 strands of No. 10 B. W. G. steel wire, seven strands of wire in each strand. They run in deep grooved pulleys in the centre of the track, except at the ends, where cylinders, having a flange on one end, are provided. On a curve, they are set on an angle, and the cable guided into them by regulating the height of the grip on the brake van. There are four elevations, 6388, 5842, 6876, 7017 feet long, respectively. Four simple low-pression engines, of 250 H.P. each, are stationed at these intervals along the road. At present they are without condensers, but are being fitted with them as rapidly as possible. The schedule is so arranged, that as one train it ascending another is descending the same section, thus effecting a great saving of coal. In the upper half of each section the cable is necessarily double, and as the expense to double-track the road would be enormous, resort is had to the very simple device of triple rails. The gauge of the road is 5 feet 3 inches and three rails are laid of this gauge, reaching from each station half way down to the next, where they divide into an ordinary double end siding, with automatic switches. On this the two trains pass, the cable adjusting itself to the pulleys in which it runs. Owing to the light traction, and the fact that the wear is always confined to the inner half of the rail, this third rail does not wear appreciably more than the outside ones. The average rate of speed up this incline is about 8.5 miles per hour, including stops.

Six trips a day are made of three cars each trip, but arrangements are being made to increase that number to four. The brake van, or grip car, has an adjustible grip for raising or lowering the cable, and also powerful brakes. From this van, by means of a telegraph line, communication can be had with the engine, which can be instantly stopped or reversed in case of necessity. At the lower end of the last section is a bridge, whose bold design is well in keeping with the rest of the work. It is 705 feet long, having a depth from rail to ground of 185 feet. It is built in 10 spans of 66 feet each, and one of 45 feet. At the upper end there is a curvature of 30 chains, and the grade on the bridge is the same as the other parts of the road, 1 in 9.75. The weight of wrought iron in the structure is 562 tons, and of cast iron

480 tons. Five hundred and seventy cubic yards of masonry were used in the abutments and piers.

To give some idea of the difficulties to be overcome, it may be mentioned that the rainfall sometimes amounts to 15 inches in 24 hours, and, in one instance, reached as high as 17.6 inches in the same time. To carry off this enormous flow of water there are 58 culverts, from 3 to 10 feet opening, beside the natural water courses. The road is graded evenly throughout the entire length, 1 foot in 9.75, so as to keep the strain on the cables constant. As an extra precaution against a coupling breaking, a short piece of cable is passed around the entire train, the ends being made fast to the brake van. All the coal used, both in locomotive and stationary engines, is brought from England. It is difficult to give any figures on the consumption of coal in the stationary engines, as it depends on so many factors, but it may be taken at about 67 kilos. per trip. The locomotives are made by Sharp & Stewart, Manchester, England. Owing to heavy grades on the road above St. Paulo, sometimes as much as 2.5 %, locomotives of 54 tons, and even larger, have to be used, though the train load is not great. Steel rails are now used of 65 pounds, and heavier have been ordered. The road has been in successful operation since 1868, and has now proved itself a success, both as an engineering work and also financially.

B. C. HOWARD.

MOMENT OF INERTIA BY A GRAPHICAL METHOD.

(READ BEFORE THE ENGINEERING SOCIETY, SEPTEMBER 29, 1892.)

The method herein described is of German origin. The writer is indebted to Prof. Klein for his knowledge of it, but does not know the name of the inventor. It is easy of application, capable of a high degree of accuracy, and offers a very satisfactory solution of what is, in most cases, a tedious problem. For these reasons it is worthy of the attention of Lehigh's future engineers, and the writer submits it to them with the hope that they may find it useful.

Primarily this method is applicable to plane figures only; but after certain preliminary work has been performed, it may be used to determine volumes, centers of gravity, and moments of inertia of bodies of irregular form with reference to all three dimensions. To illustrate the manner of procedure, and demonstrate the correctness of our conclusions, we will take the simplest case, and assume, Fig. 1, a plane area bounded by the base line AB and the irregular curve MNO.

Through this figure we draw a series of parallel lines, perpendicular to AB, spacing them according to considerations which will be brought out later. Next we draw, without the figure, two axes, one on each side, at a convenient distance and also perpendicular to AB. One of them, as AA' we may call the moment axis, and the other, BB' the reference axis. We now proceed to derive from the original curve MNO two other curves, from which we shall be able to determine the vertical ordinate on which lies the center of gravity of the figure and the moment of inertia of the area about this vertical axis through the centre of gravity.

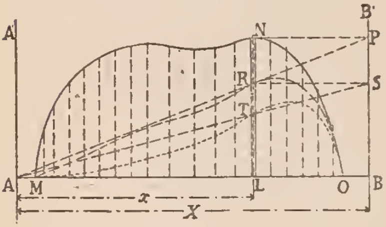

FIG. 1.

The construction is as follows: take any ordinate as NL, project the point N upon the refence axis BB', and find the point R where the line joining A and P intersects the ordinate NL; similarly, project R on BB' at S and find T by drawing AS. R is a point of the first, and T of the second, derived curve; and by performing the operation for each ordinate, we obtain enough points to enable us to trace the two curves MRO and MTO.

Now, with a planimeter, we measure the area S_1 of figure $MNOM$; S_2 of the figure $MROM$ bounded by the first derived curve; and S_3 of $MTOM$ bounded by the second derived curve. The following relations will be shown to hold true:

$$AG = \frac{S_2}{S_1} \times X. \qquad (a)$$

where AG is the distance from AA' of the center of gravity (see Figs. 2 and 3), and X is the distance AB; and

$$I_A = S_3 X^2 \tag{b}$$

in which I_A is the moment of inertia of $MNOM$ about the axis AA'. The principal moment is obtained by using the regular formula for transferring, so that

$$I_P = S_3 X^2 - S_2 (AG)^2 \tag{c}$$

is the moment of inertia about the axis GG' (see Fig. 2).

The demonstration is simple, in fact, if not in appearance. In Fig. 1 let the ordinates, measured from AB, be, for S_1, y_1; for S_2, y_2; and for S_3, y_3; so that for the particular position chosen, $NL = y_1$, $RL = y_2$ and $TL = y_3$; and let the abscissas x be measured from AA'. Consider a strip of width dx, so that

$$\begin{aligned} &\text{strip } NL = y_1\, dx = dS_1 \\ &\text{strip } RL = y_2\, dx = dS_2 \\ &\text{strip } TL = y_3\, dx = dS_3 \end{aligned} \tag{d}$$

Now, from the similar triangles PAB, RAL,

$$\begin{aligned} &PB : AB :: RL : AL, \text{ or} \\ &y_1 : X :: y_2 : x, \text{ whence} \\ &xy_1 = Xy_2. \end{aligned} \tag{e}$$

Now multiply both sides by dx, and we have

$$\begin{aligned} xy_1\, dx &= X y_2\, dx \\ xd\, S_1 &= Xd\, S_2 \\ \int x\, dS_1 &= X \int dS_2 = XS_2. \end{aligned} \tag{f}$$

We know that $\int x\, dS_1$, taken within the proper limits, is the moment of S_1 about the axis AA'; and from a well known principal of mechanics, this is equal to $S_1 \times AG$, when SG has the significance already given to it, therefore

$$AG = \frac{S_2}{S_1} X.$$

Again in the similar triangles SAB, TAL,

$$SB : AB :: TL : AL \text{ or } xy_2 = Xy_3 \tag{g}$$

from (e) $y_2 = \frac{x}{X} y$, and (g) becomes when multiplied by dx,

$$\begin{aligned} &x^2 y_1\, dx = X^2 y_3\, dx, \text{ and} \\ &\int x^2\, dS_1 = X^2 \int dS_3 = X^2\, S_3. \end{aligned} \tag{h}$$

Now, $\int x^2 \, ds_1$ is the moment of inertia of S_1 about AA_1, and we know the value of the equivalent expression $X^2 S_3$; therefore

$$I_A = X^2 S_3,$$

as already stated.

What we have in S_2 and S_3 is this: S_2 is an area such that, *if concentrated at the axis* BB', its moment about AA' will be the same as that of the area S_1; and S_3, if similarly concentrated at BB' has the same moment of inertia about AA' that S has in its distributed state. A simple proof can be worked out along this line, but it seems as if the one given is better, in that it shows rigorously that the method is an exact one.

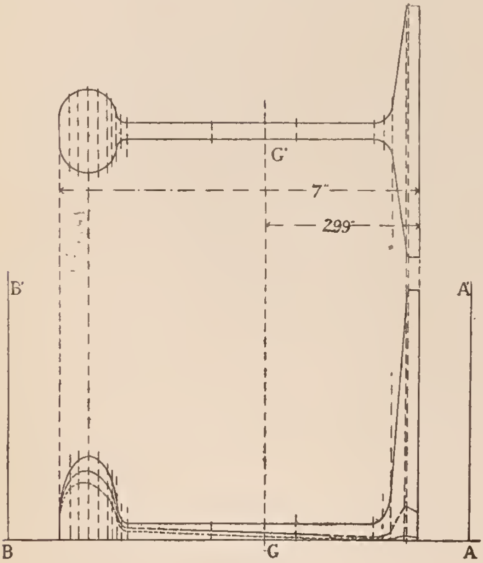

FIG. 2.

Fig. 2 is an example of the application of this method to a seven-inch deck-beam of Carnegie, Phipps & Co.: here $S_1 = 5.3$ square inches, $S_2 = 2.35$ and $S_3 = 1.50$; $X = 9''$, and AA' is $1''$ from the edge of the section.

$$AG = \frac{2.35}{5.30} \times 9 = 3.99''$$

$$I_P = 1.50 \times 9^2 - 5.30 \times 3.99^2 = 121.5 - 84.4 = 37.1 \text{ inches.}$$

The catalogue gives 38.8, and when it is seen that a change of .01 square inch in S_2 or S_3 will affect the value of I_P by about half a unit, we appreciate how much graphical accuracy is needed. A rather hasty working may account for the discrepancy in this case; closer ordinates might give better results. The method is certainly capable of great accuracy, and is very convenient for making determinations upon beam and rail sections.

Of course, it is always necessary to transform the given area into one bounded by the base line *AB*, as is done in Fig. 2. This is accomplished by drawing ordinates through the section, and, from the base line *AB*, laying off the intercepts which the outline of the figure cuts from each ordinate; the necessary condition to be fulfilled in such a transformation is, *that the distribution of the area in the direction in which the moment arms are measured — that is, parallel to AB — must not be changed:* and it is readily seen that this condition is satisfied.

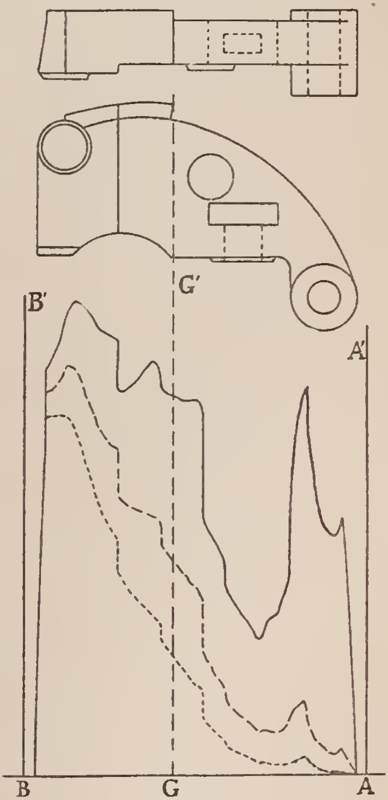

FIG. 3.

When we take up bodies of varying thickness, as the governor weight in Fig. 3, the work is not so simple. The first thing to be done is to reduce the given body to an equivalent area of the required form. Having an accurate scale drawing of the piece, showing at least two views, we draw through the main view a series of ordinates as usual, and conceive a plane passed through each ordinate perpendicular to the plane of the paper. Each of these planes cuts the body in a section of definite form, and for each cutting plane we determine the area of the corresponding section. This is the most tedious part of the work, and gives many opportunities for the use of labor-saving "short cuts." Having determined these areas, we choose a base line *AB* at right angles to the ordinates, and from it lay off on each ordinate a length equal to the number of square inches in the corresponding section: (the use of ordinates of half or quarter size may be necessary, in which event the areas S_1, etc., must be multiplied by 2 or 4 as the case may be). Now if we consider the area thus obtained to represent a disc or plate 1″ thick, we see that it fully represents the given body, and satisfies the condition given above as to the distribution of material. We can now treat this exactly as in the case of a plane figure, determining the vertical line on which lies the centre of gravity, and the rectangular moment of inertia about this line. To determine the centre of gravity and the polar moment of inertia, we must draw a set of ordinates at right angles to the first, and go through the whole operation again. The centre of gravity then lies at the intersection of two lines, or strictly speaking, of the two planes; it is still not fully determined, but in this case only the axis through it, normal to the principal plane of the piece is required. The polar moment with respect to this principal axis is the sum of the two rectangular moments already determined.

In such a case as this we have the additional advantage that the area S_1, in square inches, is numerically equal to the volume of the body in cubic inches; and there is a check upon the accuracy of the work in the fact that the volumes of S_1 from the two determinations should be the same. Also, that the moment of inertia of the area is equal to that of the volume, is evident from the fact that the numerical value will not be changed by the factor unity which represents the thickness of the disc to which the body has been reduced.

A word as to a few practical details. Aside from good instruments and careful measurements, the degree of accuracy depends upon the spacing of the ordinates and the tracing of the curves. For beam section, where, relatively, a good deal of time is available, the ordinates can be taken very close together; but when rapid work must be done, judicious use of the variable curve between more distant ordinates counts for a great deal. In any case, the ordinates should be crowded together where the section is changing rapidly, and strung out where it is nearly constant. In work such as is shown in Fig. 3, of which a connecting rod would be a good example, the distance would vary from a quarter of an inch, or less, in the ends, to three or four inches in the shank of the rod. Again, since the position of the axes AA' and BB' is arbitrary, it is always well to take them a whole number of inches from each other, and from some important point of the body or section. There are some other minor points which might be mentioned, but enough has been said to show the good points of this method, and to enable any one to use it with success.

ROBERT C. H. HECK, '93.

A 'VARSITY MAN IN PARIS.

It was a very warm and dusty Sunday morning, I remember, when we steamed slowly into Paris. I say *we*, for, having been foolish enough to take a third-class compartment, I sat just opposite what seemed to be a gypsy woman, with a baby and a very large bundle of very dirty clothes. I don't know much about babies, but think it safe to assume that this baby was very warm and uncomfortable, for, entirely oblivious to the attractions of a greasy bone which his mother from time to time picked up off the floor and offered him to suck, he squalled without cessation all the way from Dieppe. The father smoked a cheap cigar and dozed quietly through it all, while the exasperated passengers in the neighboring compartments threw cakes and oranges over the partition, vainly hoping to get a moment's peace by filling the child's mouth with sweets.

In my eagerness to learn French I could have stood the fretting of a French child,—but the bawling of a gypsy brat! Well, take a bit of friendly advice—don't ride third class in France.

My only relief was trying to decipher the signs on the stores and warehouses, and I felt much more at home when I saw the advertisements of Van Houten's Cocoa, Armour's Extract of Beef, and even Sunlight Soap on every hand (except on the gypsy's).

The Frenchman, by the way, has a mania for posting bills and advertisements, and even the walls of the churches bristle with the unsightly *Défense d'afficher*.

The average university graduate knows French. He is familiar with Whitney's grammar; has read quite a number of French novels, and while he has never had any great practice in speaking the language, he has a pretty good idea of the nasal sounds, and has studied hard over such points as the lip position for the French *u*,—in short, is quite confident of his ability to get along, if he *don't* claim to speak fluently.

I was a 'Varsity man off for a Summer's study in Paris; I had all the theory of the language well "boned up," and was surprised and grieved to find that the man in blue uniform, who snatched and ran off with my valise after the French custom, could not understand the language at all. The blank expression and shrug of the official to whom I appealed against the porter's modest charge of two francs, was sufficient to convince me that there was something foreign in my accent, and, paying the porter to get rid of him, I determined not to be "done" by the cabman too, and, therefore, did not engage him until I had made the trip afoot. Sure enough, the cabby "spotted" that foreign element which again cropped out in spite of the many times I repeated the sentence to myself in order to insure a quick and accurate delivery. The rascal made a long *détour*, expecting and demanding twice the usual fare, but this time my blood was up, and in a vigorous, if not elegant, mixture of English and French and profanity, I told him I had been "done" enough for one morning, and paying just the bare amount, fled into the house, pursued by a volley of oaths.

Possibly you think it easy to pick up French in a *pension*. Try it. In the first place they are hard to find, and, as the French are second only to the Chinese in conservativeness, when you do find a good one it is by no means easy to get intimate with the family. You pay so much a month, and are asked a certain number of times a day how you carry yourself, whether you expect to promenade yourself this afternoon, etc., etc. And beyond this the intimacy rarely extends. In my pension in the Latin quarter we had a splendid opportunity to acquire a cosmopolitan accent, as our circle consisted of madame, her husband, two Germans, a Swiss, a Swede, a Norwegian, and, lastly, two Englishmen. In this list I don't include a Roumanian, for he took only his lunch with us.

Unfortunately no Summer courses were offered to students at the University, so after a little cosmopolitan French at home, I would climb on the *impériale* of an omnibus and for three sous ride to the *Théâtre français*, where a franc paid for a seat in the pea-nut gallery and three hours of good French. If not in a hurry it is amusing to *faire queue*, as they say, before the ticket office. I have often waited several hours in this way, willingly, too, for the surliest man will talk in such a position.

But it is slow work at best, living in a big city without friends, and had it not been for the Louvre, and the Luxembourg gallery and garden — a fine place to read — the time would have hung heavy on my hands. And then, of late years, there is no little ill feeling between the French students of the Latin quarter and their American and English rivals. The former say their enforced military service handicaps them and the foreigners get too many scholarships, hospital appointments, etc. As a rule they are unsociable, and one can hardly blame them, for there is little pleasure in talking with a man who understands but half of what is said. Some of my friends go to Paris, bury themselves in the *Bibliothèque Nationale*, take morning coffee in their rooms and dine in the cafés, learning just about as much French as if they stayed at home.

Of course if a man has money he can hire a nice fellow to walk, talk and dine with him, but the average student is not wealthy, and speaking to him, I should say, go out in the suburbs, find some big old country house where the real French life can be seen. I know it is feasable, for I was two months in such a home and became very familiar with one phase at least of French society, and very pleasant it was, too — the Sunday déjeuner with all the town friends and relations around the festive board, the *petit verre* after *dessert*, then a *partie de bouchon* — a quaint game something like pitching pennies or '*duck-on-a rock*' — the usual *partie de pêche* for the grown people, the carefully chaperoned walk for the young folks, and finally, after the elaborate course dinner on the lawn, a dance, singing, *bèsigue* and whist. Sundays such as this, many a game of *billard*, many a long bicycle ride with the young men in the neighborhood would, doubtless, be lost time for my manuscript-loving philological friends, but for the student of the spoken language, and of the manners and customs of the nation who speak it, such a Summer is full of interest and instruction.

W. STUART SYMINGTON, JR.

EDITORIAL.

WITH this issue we introduce the QUARTERLY of '93 to the University and to all who may be interested in its welfare. We shall proceed in general on the lines laid out by our brother editors, and shall endeavor to publish only such matter as will be of interest to the practical engineer and student. To further the interests of this, Lehigh's only scientific journal, we need the hearty coöperation of both alumni and students, and we trust that this interest will be shown in a very material addition to our subscription list.

In the editorial columns of a professedly scientific and literary journal we see the need of expressing our views on numberless questions of interest of the day, but owing to the very limited time a college man has to put on any but regular work, we feel that more than a mere mention of these matters of interest is impossible, and so our editorial column will confine itself to matters of every day college affairs.

To the alumni we would like to say that the QUARTERLY will publish the best prepared articles on any scientific subject; and we sincerely hope that every alumnus will deem it his pleasure, and a duty to his *alma mater*, not to wait till he is urged for a paper on some specific subject, but to send of his own accord all such matter for publication as he may think will be of general interest.

We call particular attention to Prof. Williams' paper on the "Reading Combination from the Standpoint of the Miner," as it seems that the public has a very hazy idea of this situation, which is one of such great importance, owing to the very material change it has made in the cost of one of the prime necessities of life.

To the student of crystallography Mr. Barrell's very complete presentation of his methods will prove of signal assistance. We also call especial attention to our very complete *Index Review* which extends back to February, and is of such great practical value in looking up a particular subject.

We announce the election of Mr. Robert C. H. Heck to the QUARTERLY Board, to fill the vacancy made by Mr. Evans' resignation.

IT would be hard to express the surprise as well as pleasure we felt on seeing the new Physical Laboratory so well under way when college opened this Fall.

The dream of the minstrel man of last term is being realized, and one year from now Lehigh can boast of a Physical Laboratory that far outsteps all others of the kind in this country.

The building will be 216 feet in length and 55 feet in width, making it three feet shorter and eleven feet wider than the Chemical Laboratory.

In the east basement, and floor above, the use of iron in construction will be entirely avoided, as all delicate experiments in magnetism will be carried on in this part of the building. The nails, hinges, locks, pipes, radiators, etc., will be made of brass, and all beams will be made of wood.

Under the north-eastern part of this building there will be an even temperature vault, which is expected to vary in temperature not more than 1° C. during the entire year. This will be used for calibrating instruments, testing resistances, and for all other experiments where extreme accuracy is desired and even temperature necessary.

The facing of the entire building will be broken range work equal to that of the Chemical Laboratory, the chimneys being dark red pressed brick.

The east end of the third story, which is to be devoted to Photography, will be so arranged that it can be divided into ten dark rooms by means of movable partitions.

The tower, 125 feet high, will add greatly to the appearance of the building, at the same time affording a most favorable position for rooms devoted to spectroscopic aud meteorological work.

A large hand elevator, with a capacity of 2000 pounds, will be run from the basement to the third floor.

The building will be completed by the first of next August, and, it is thought, will be ready for occupancy by the beginning of the Fall term.

When completed and equipped, the cost will approximate 250,000 dollars.

This well directed improvement will greatly increase the efficiency of the Electrical course at Lehigh, as well as add beauty and completeness to her now unrivaled campus. The plans reflect much credit upon Prof. Harding, who made them, and upon Mr. Houskeeper, who assisted him.

WHAT a tremendous increase in class feeling has been shown in our new method of establishing the lordly Sophomore's supremacy over the Freshmen. We hope to see the games of Columbian Day established firmly as a precedent, to take place annually at some specified time, and thus, without the dangers and rowdyism of the cane-rush, test the physical abilities of the lower classes.

MANY of the upper classmen remember the close contests between the Sophomores and Freshmen, when there were regular base-ball, foot-ball, and lacrosse games between the classes; the winning teams of the upper and lower classes then playing each other for the class championship.

Why not renew this custom? It is followed at Yale, Princeton, University of Pennsylvania, Cornell, and other colleges, and is a great factor in developing material for 'Varsity teams. The disastrous score made by Cornell against us, will naturally make old Lehigh men anxiously inquire whether Lehigh is losing her athletic spirit. But this can not be so, for have we not now nearly twice the number of men we had in those days when we played Cornell and University of Pennsylvania, even, and held Princeton down to small scores?

The scheme could be very materially aided, if a trophy is offered for the winning team, either by the athletic association, or else by the united action of the classes. And for the sake of athletics here at Lehigh we hope that some means will be devised of developing such talent as at present is content with doing nothing.

IT is with great regret that we see several of our best men about to leave for breaking one of the University rules—that as to hazing. We do not presume to criticize the action taken by the faculty in this matter, but in view of the very severe punishment meted out to these men, we feel it our duty to voice the college opinion, which is quite united. These men undoubtedly hazed the boy who made the complaint, and in so doing broke a University rule, for which some punishment was right and proper. But are there no extenuating circumstances? Should not in this case the punishment be very much tempered with mercy? We think so: and why? The boy, who is not in the University, had made himself very objectionable to some of the students, and needed some of the starch taken out of him. In the early part of the practical joking he was quite in the humor for it, and made the remark to a bystander that he wanted to be hazed. There was no maliciousness whatever in the actions of the students, and it has been positively asserted that no injury was done the boy beyond a slight bruise due to an accidental fall.

As for the indignities heaped upon him, we think most decidedly that some step should be taken to make this a lesson to students in the future; but should those steps go to the extreme of preventing two men from ever getting an education, and putting a slur on their names that will last through their lives? We think not.

The students concerned are not at all of the rowdy element in college, never having in any way participated in hazing before, and simply went into it with an idea of having some fun. The subsequent actions of the hazed boy have shown him up in a very unenviable light, as it has been stated under oath, that he had made the statement that he intended making money out of the whole affair. We think there was no leadership in the matter, and all the men concerned are equally culpable, and though richly deserving punishment, we do not think the offence great enough to expel anyone of them, and we sincerely hope that the petition to be put before the faculty may have its desired effect of limiting the suspension from college in each case till January.

[Since our last writing the faculty has reconsidered its action, and on the signing of a pledge by the individual men of both the lower classes, all the students engaged have been reinstated in full standing, and we should congratulate ourselves that the matter has been settled so satisfactorily to all parties.—EDS.]

IT is a very difficult matter to write of a delicate point of honor without stepping rough-shod over people in general; and to avoid the inevitable—"people in glass houses"—let us start by saying that most of us do it more or less. Yes, to our shame be it said, "Ponying" has gotten to be almost a college custom. Right here lies the trouble. We say, "well, everybody ponies; we make no secret of it; the Faculty knows it, and where is the harm?" Or, we say this, and even think it outwardly, but down in the bottom of our hearts we know that it is small and unmanly, and we individually would be only too glad to see the whole thing abolished, and this black line erased from across each day of our college life.

Who is there who has not known the great pleasure of making a 10 in Mathematics with no assistance whatever, and who is there who would not like to see Lehigh cleared of this slur? No one. Is there no way of 'making a beginning? Is there no stand we can take to stop the thing among the men who have just entered and who have not as yet become as indifferent to it as we ourselves? Think of the injustice to the man who, from having his ideas knocked into him before he came here, tries to get his degree by himself. It is very certain that the standard of the University must be raised by this custom, and we might say that a man is almost driven to ponying for this reason.

We will not make any comparison between places, but it is a well known fact that where college sentiment is down on such doings, a man is ashamed of the practice, and except in rare cases it becomes an unknown factor in recitations and examinations.

DURING the past year the athletic field has been the recipient of much attention both editorial and financial, which has resulted in a number of beneficial changes. It was generally considered that the final arrangement of the foot-ball field, the diamond, and the track was the best that could be made under all the restricting conditions. But now it has become apparent that at least one feature of the field is sadly out of harmony with the rest, and that is the track. Dividing, as it does, the base-ball and foot-ball fields, it is a detriment to both. It almost spoils the left and centre fields; it restricts the lacrosse field to less than the space required under the rules of the Intercollegiate Association; and forces the foot-ball field entirely too far toward the western fence. At the same time it makes it a matter of difficulty to get a straight hundred, and requires almost five laps to the mile. As it stands the track will have to undergo considerable improvement, and while this is being done would it not be well to make a change of such a nature as to remove some, if not all, of its present faults? Such a change we think could be accomplished by extending the track across the diamond, and making the turns close to the eastern fence, bringing it back through the right field. This move would not entail much expense, for, assuming the grade constant on the south side of the track, the greatest fill required, that on the northeastern corner of the field, would be but 18 feet, and could be made almost entirely from the fill that at present separates the two fields. The diamond is now on exactly the same grade as the track in front of the grand stand, and thus that would not be interfered with in the least.

The advantages which would be obtained are many. The lacrosse and foot-ball field would be unrestricted. There would be no difficulty in getting a straight hundred, and a two-twenty could be had with but one turn. A mile could be made in about three laps. By allowing the foot-ball field to move farther east, the turns on the western side could be much eased, and the track would be open to bicyclers, for now the turns are too sharp to admit of any speed like that of a bicycle race. The disadvantage of obstructing the right field would be more than counterbalanced by the opening of left and centre fields. As we mentioned before, the track is now in a very bad condition. Some of the turns slope out instead of in, and it is in some places between one and two feet below grade. These things will have to be remedied this Spring, and we would earnestly request the Athletic Association to give serious thought to the changes indicated above, and we sincerely hope that either this or some better plan will be adopted to avoid in the future the incoveniences that have been caused in the past.

There seems to be very little of a clear understanding to the amendments to the By-Laws of the Athletic Association made last Spring by the college, and as these amendments have been temporarily mislaid, a few words might help to explain their salient points. All funds, both from collections and gate receipts, will be handed over to the Treasurer of the Athletic Association, who will give a receipt for same. All disbursements of money will be made by the Executive Committee of said Association in such proportion to each branch of athletics as they may see fit. Thus the financial matters of the Association will be put on a much firmer basis, and it is hoped that the whole college will be benefited by the change. The students will be asked for but one subscription of five dollars for the support of athletics, and as the collection of this money is to be put systematically into the hands of men from each class, we feel quite sure that the larger portion of it will be realized.

FOR LEHIGH MEN.

This column will contain, chiefly, such information in regard to addresses and occupations of Alumni as does not appear in the latest issue of the *Lehigh Register*. Please contribute.

'78. M. P. Paret, charge of Harbor Surveys, Baltimore, Md.

'83. Charles C. Hopkins, Stanwix Eng. Co., Rome, N. Y.

'87. James W. Kittrell, Stanwix Eng. Co., Rome, N. Y.

'87. R. W. Barrell, E.M., Manager of Assaying Dep't of Golden Leaf Limited, Cavendish, Montana.

'88. C. L. Banks, B.S., M.D., House Surgeon at Post Graduate Hospital, 226 East 20th Street, N. Y. City.

'88. O. C. Burkhart, E.M., Instructor Colliery Engineering, School of Mines, Coal Exchange, Scranton, Pa.

'88. A. T. Bruegel, M.E., Instructor of Mechanical Engineering at Cornell.

'88. W. L. Wilson, C.E., 1016 Vermont Avenue, Washington, D. C.

'89. W. D. Farwell, B.A., City Editor, Newark Daily Advertiser.

'90. C. E. Coxe, E.M., Sup't Bessie Furnace, Columbus & Hocking Valley Coal & Iron Co., New Straitsville, O.

'90. F. R. Coates, E.M., Supervisor of Wheeling & Pittsburgh Branch of B. & O. R. R., Washington, Pa.

'90. F. R. Barret, C.E., Assistant Engineer, Norfolk & Western R. R., care of W. H. Hall, Division Engineer, Elkhorn, W. Va.

'90. W. S. Cope, C.E., Assistant Engineer, Norfolk & Western R. R., care of W. H. Hall, Division Engineer, Elkhorn, W. Va.

'90. C. H. Detwiler, C.E., Inspector of Masonry, Norfolk & Western R. R., care of W. A. Duane, Principal Assistant Engineer, Venora, W. Va.

'90. C. E. Fink, C.E., Inspector of Masonry, Norfolk & Western R. R., care of W. A. Duane, Principal Assistant Engineer, Venora, W. Va.

'90. F. K. Houston, M.E. F. K. Houston & Co., cuts for advertisements; 324 Broadway, New York City.

'90. J. S. B. Hollingshead, E.M., Reduction Works of Boston & Montana Consolidated Silver and Mining Co., Great Falls, Mont.

'90. W. C. Riddick, C.E., Professor of Mathematics, University of North Carolina.

'90. F. D. Thomson, M.E., Manager of Blast Furnaces, Edgar Thompson Works, Braddock, Pa.

'90. A. H. Van Cleve, C.E., with Niagara Falls Power Co.

'90. C. W. Platt, A.C., Secretary and Treasurer of Vandenbergh Laboratory of Chemical Industry, corner Swan and Washington Streets, Buffalo, N. Y.

'90. C. A. P. Turner, C.E., with Columbus Bridge Co., Columbus, O.

'91. E. H. Coxe, C.E., with Norfolk & Western R. R., Dunlow, W. Va.

'91. W. A. Heindle, C.E., Engineering Department Baltimore City Passenger R. R. Co., Baltimore, Md.

'91. H. M. Knapp, C.E., with Berlin Bridge Co., Berlin, Ct.

'91. H. V. Hesse, E.M., Lehigh & Wilkes-Barre Coal Co., Audenried, Pa.

'91. W. F. Rench, C.E., with P. R. R., care of Assistant Engineer P. W. & B. R. R., Delaware.

'91. J. E. Talmadge, Professor of Physics and Chemistry, Salt Lake City, Utah.

'91. W. S. Topping, L.S., Student Chicago College of Pharmacy, 149 Sacramento Ave., Chicago, Ill.

'92. R. L. Baird, C.E., with Norfolk & Western R. R., care of W. H. Hall, Division Engineer, Elkhorn, W. Va.

'92. J. N. Bastress, C.E., with Norfolk & Western R. R., care of W. H. Hall, Division Engineer, Elkhorn, W. Va.

'92. S. D. Cushing, M.E., with General Electro Co., Schenectady, N. Y.

'92. M. Davis, B.S., care of Irving A. Stem, Wilkes-Barre, Pa.

'92. T. Gjertsen, C.E., with Norforlk & Western R. R., care of W. H. Hall, Division Engineer, Elkorn, W. Va.

'92. J. J. Jimenez, C.E., with Norfolk & Western R. R., care of W. H. Hall, Division Engineer, Elkhorn, W. Va.

'92. R. R. Kitchel, M.E., with Cutter Silk Manufacturing Co., Bethlehem, Pa.

'92. W. R. Davis, C.E., with Allentown Bridge Co., Allentown, Pa.

'92. F. D. Randolph, M.E., Head Draughtsman, C. Potter, Jr., & Co., Manufacturers of Printing Presses, Plainfield, N. J.

'92. J. C. Shriver, B.S., with Allentown Bridge Co., Allentown, Pa.

'92. L. W. Walker, E.E., Assistant Superintendent Electric Power Co., Savannah, Ga.

'92. R. B. Olney, C.E., with Norfolk & Western R. R. Co., care of W. H. Hall, Division Engineer, Elkhorn, W. Va.

'92. D. H. Witmer, C.E., with Norfolk & Western R. R. Co., care of W. A. Duane, Principal Assistant Engineer, Kenova, Va.

'92. F. Wittman, A.C., Lehigh Valley Zinc Works, Bethlehem, Pa.

'92. B. E. Woodcock, 332 Broadway, Pueblo, Cal.

John W. Ledoux, Engr. Am. Pipe Manufacturing Co., Philadelphia, Pa.

'92. P. L. Cobb, Brooklyn Electric Railway Co., 49 St. Johns Place, Brooklyn.

'92. Heber Denman, Bewind White Coal Co., Horatio, Pa.

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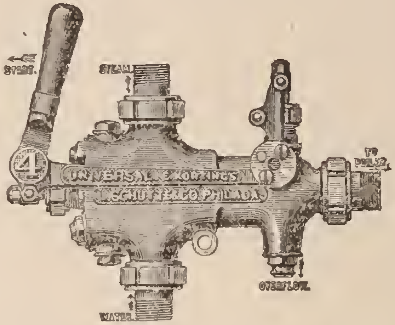

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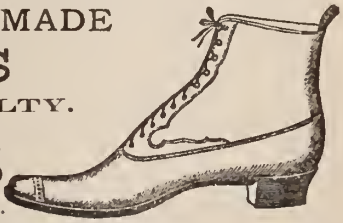

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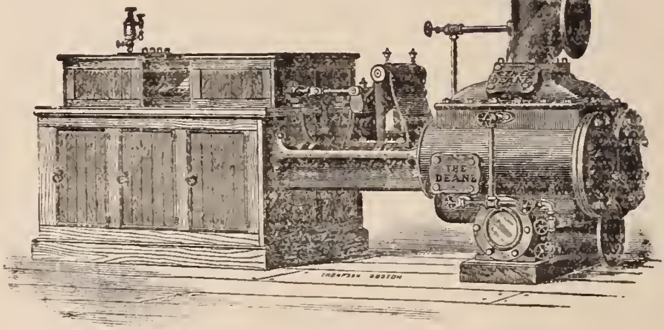

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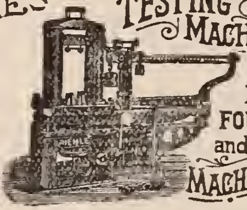

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